KOREA 2025 수학

EARCOME9

The 9th ICMI-East Asia Regional Conference on Mathematics Education

Re: Visiting the Essence of Mathematics Education in the Era of Digital Transformation

JUL. 18 FRI ~ 22 TUE, 2025

Seoul National University, Siheung Campus

Proceeding Vol. 2

- Working Groups
- Special Sharing Groups
- Poster Presentations

Co-Host
대한수학교육학회 The Korean Society of Educational Studies in Mathematics
한국수학교육학회 The Korean Society of Mathematical Education

KOREA 2025

EARCOME9

The 9th ICMI-East Asia Regional Conference on Mathematics Education

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Welcome Message

It is with great pleasure that we welcome you to the 9th ICMI-East Asia Regional Conference on Mathematics Education (EARCOME 9), held from July 18 to 22, 2025, at Seoul National University's Siheung Campus in South Korea.

EARCOME has become a cornerstone for mathematics education in East Asia, bringing together researchers, educators, and practitioners from across the region and beyond. Its origin can be traced to the South East Asia Conferences on Mathematics Education (SEACME), which began in 1978. Since the first official EARCOME in 1998, the conference has evolved into a triennial gathering—except during ICME years—fostering collaboration, scholarly exchange, and innovation in mathematics education.

The theme for EARCOME 9, "RE: Visiting the Essence of Mathematics Education in the Era of Digital Transformation," invites us to reflect deeply on foundational principles in mathematics education amid the profound shifts driven by digital technology. In this transformative age, questions of purpose, practice, and pedagogy are more urgent than ever.

As the International Program Committee Chair and Co-Chair, we are honored to support a program that reflects the diverse voices and vibrant scholarship across East Asia and beyond. This year's conference is co-hosted by The Korean Society of Educational Studies in Mathematics (KSESM) and The Korean Society of Mathematics Education (KSME). It includes an exceptional lineup of plenary lectures, invited presentations, topic study groups, and practice-oriented sessions for practitioners.

We extend our deepest gratitude to the Local Organizing Committee, co-chaired by Ho Kyoung Ko (Ajou University), GwiSoo Na (Cheongju National University of Education), and Jinho Kim (Daegu National University of Education), whose dedication and leadership have been instrumental in realizing this event. We also acknowledge the many LOC members and volunteers who have contributed their time and expertise to make EARCOME 9 a meaningful and enriching experience.

We are especially grateful for the generous support of the National Research Foundation of Korea (NRF), funded by the Ministry of Education (MOE), under Grant No. NRF-2025S1A8A4A01014320. Their support has been crucial in making this conference possible.

We warmly welcome you to EARCOME 9 and invite you to engage fully in the discussions, share your insights, and help shape a forward-looking, inclusive vision for mathematics education. We hope this conference will not only deepen your academic inquiry but also strengthen our shared commitment to building a collaborative and culturally grounded mathematics education agenda in East Asia.

Oh Nam Kwon
Chair, International Program Committee
Seoul National University, South Korea

Berinderjeet Kaur
Co-Chair, International Program Committee
National Institute of Education, Singapore

	July 18(Fri)		July 19(Sat)		July 20(Sun)	
08:30~09:00			Networking		Networking	
09:00~09:30			Exhibition	**Plenary Panel Discussion 1 (CH)**	Exhibition	**Plenary Lecture 2 (CH)**
09:30~10:00						
10:00~10:30				Coffee Break		Coffee Break
10:30~11:00				**TSG 1 (#109)**, **TSG 2-1 (#CH-A)**, **TSG 2-2 (#CH-C)**, **TSG 3 (#102)**, **TSG 4-1 (#603)**, **TSG 4-2 (#604)**, **TSG 5 (#806)**, **TSG 6-1 (#605)**, **TSG 6-2 (#606)**, **TSG 7 (#806-1)**, **TSG 8 (#103)**, **TSG 9 (#406)**, **TSG 10 (#609)**		**TSG 1 (#109)**, **TSG 2-1 (#CH-A)**, **TSG 2-2 (#CH-C)**, **TSG 3 (#102)**, **TSG 4-1 (#603)**, **TSG 4-2 (#604)**, **TSG 5 (#806)**, **TSG 6-1 (#605)**, **TSG 6-2 (#606)**, **TSG 7 (#806-1)**, **TSG 8 (#103)**, **TSG 9 (#406)**, **TSG 10 (#609)**
11:00~11:30						
11:30~12:00						
12:00~12:30						
12:30~13:00				Lunch/Networking		Lunch/Networking
13:00~13:30	Exhibition	**Registration**				
13:30~14:00						
14:00~14:30				**Invited Lecture 1-1 (CH)**, **Invited Lecture 1-2 (#109)**, **Invited Lecture 1-3 (#806)**, **Invited Lecture 1-4 (#806-1)**		**Invited Lecture 2-1 (CH)**, **Invited Lecture 2-2 (#109)**, **Invited Lecture 2-3 (#806)**, **Invited Lecture 2-4 (#806-1)**
14:30~15:00						
15:00~15:30				**Poster Presentation 1 (1F Lobby)**		**Poster Presentation 2 (1F Lobby)**
15:30~16:00						
16:00~16:30				Coffee Break		Coffee Break
16:30~17:00		**Opening Ceremony (CH)**		**WG 1-1 (#109)**, **WG 1-2 (#606)**, **WG 1-3 (#605)**, **WG 1-4 (#806-1)**, **SSG 1-1 (CH)**, **SSG 1-2 (#806)**, **SSG 1-3 (#603)**, **SSG 1-4 (#604)**		**WG 2-1 (#109)**, **WG 2-2 (#806-1)**, **WG 2-3 (#605)**, **WG 2-4 (#606)**, **SSG 2-1 (CH)**, **SSG 2-2 (#806)**, **SSG 2-3 (#603)**, **SSG 2-4 (#604)**
17:00~17:30		**Plenary Lecture 1 (CH)**				
17:30~18:00						
18:00~20:00		**Welcome Reception (2F Lobby)**				

*** TSG** | Topic Study Group
*** WG** | Working Group
*** SSG** | Special Sharing Group
***CH** | Convention Hall

Program at a Glance

	July 21(Mon)	July 22(Tue)
08:30~09:00	Networking	Networking
09:00~09:30	Exhibition **Plenary Lecture 3 (CH)**	Exhibition **Invited Lecture 3-1 (CH)** **Invited Lecture 3-2 (#109)** **Invited Lecture 3-3 (#806)**
09:30~10:00		
10:00~10:30	Coffee Break	Coffee Break
10:30~11:00	**TSG 1 (#109)** **TSG 2-1 (#CH-A)** **TSG 2-2 (#CH-C)** **TSG 3 (#102)** **TSG 4-1 (#603)** **TSG 4-2 (#604)** **TSG 5 (#806)** **TSG 6-1 (#605)** **TSG 6-2 (#606)** **TSG 7 (#806-1)** **TSG 8 (#103)** **TSG 9 (#406)** **TSG 10 (#609)**	**Plenary Lecture 4 (CH)**
11:00~11:30		
11:30~12:00		**Closing (CH)**
12:00~12:30		
12:30~13:00	Lunch/Networking **IPC & AB Meeting (#102)**	
13:00~13:30		
13:30~14:00		
14:00~14:30	**Plenary Panel Discussion 2 (CH)**	
14:30~15:00		
15:00~15:30	Coffee Break	
15:30~16:00	**WG 3-1 (#109)** **WG 3-2 (#806-1)** **WG 3-3 (#605)** **WG 3-4 (#606)** **SSG 3-1 (CH)** **SSG 3-2 (#806)**	
16:00~16:30		
16:30~17:00		
17:00~17:30		
17:30~18:00		
18:00~20:00	**Conference Banquet**	

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Working Groups

Working Groups 1	
July 19, Saturday	
Working Group 1-1	
16:30~18:00	**EXPLORING MATHEMATICS LESSONS FOR FOSTERING MATHEMATICAL THINKING** Yujin Seo (Korea Foundation for Science and Creativity)
Working Group 1-2	
16:30~18:00	**DEVELOPMENT OF A TEACHER TRAINING PROGRAM FOR STRENGTHENING AI DIGITAL TEXTBOOK(AIDT) UTILIZATION COMPETENCY** Seo Hyun Ahn (Ajou University)
Working Group 1-3	
16:30~18:00	**BRIDGING MINDS, BUILDING FUTURES:** **A RESEARCH COLLABORATION WORKSHOP FOR EMERGING SCHOLARS IN EAST ASIA: PART 1** Kyong Mi Choi (University of Virginia)
Working Group 1-4	
16:30~18:00	**USING GENERATIVE AI IN SECONDARY MATHEMATICS EDUCATION:** **DATA ANALYSIS, VISUALIZATION, AND GAMIFICATION** Oh Nam Kwon (Seoul National University)

Working Groups 2	
July 20, Sunday	
Working Group 2-1	
16:30~18:00	**ENHANCING TEACHERS' PRACTICAL TEACHING ABILITIES THROUGH AI-SUPPORTED CLASSROOM INSTRUCTION EVALUATION** Yiming Cao (Beijing Normal University)
Working Group 2-2	
16:30~18:00	**A SERIES OF LEARNING ACTIVITIES FOR DEVELOPING THINKING-ORIENTED MATHEMATICAL COMPETENCE** Ying-Hao Cheng (University of Taipei)
Working Group 2-3	
16:30~18:00	**BRIDGING MINDS, BUILDING FUTURES:** **A RESEARCH COLLABORATION WORKSHOP FOR EMERGING SCHOLARS IN EAST ASIA: PART 2** Kyong Mi Choi (University of Virginia)
Working Group 2-4	
16:30~18:00	**DESIGNING MATHEMATICS LESSONS USING GENERATIVE ARTIFICIAL INTELLIGENCE:** **FOCUSING ON PRACTICES AT THE SECONDARY SCHOOL LEVEL** Oh Nam Kwon (Seoul National University)

Working Groups 3

July 21, Monday

Working Group 3-1	
15:30~17:00	**TEACHING MATHEMATICS FOR SOCIAL JUSTICE: CASES FORM KOREA** Jaehoon Shim (Seoul Inheon Elementary School)
Working Group 3-2	
15:30~17:00	**MATHEMATICAL HABITS OF MIND:** **A FRAMEWORK FOR UNDERSTANDING AND SUPPORTING POSITIVE DISPOSITONS TOWARD MATHEMATICS LEARNING** Jihwa Noh (Pusan National University)
Working Group 3-3	
15:30~17:00	**POETIC METHODS IN MATHEMATICS EDUCATION** Pauline Tiong (National Institute of Education)
Working Group 3-4	
15:30~17:00	**REPLACING STEAM WITH STEEM TO ALSO INCLUDE ECONOMICS** Allan Tarp (MATHeCADEMY.net)

Special Sharing Groups

Special Sharing Groups 1

July 19, Saturday

Special Sharing Group 1-1	
16:30~18:00	**IN-DEPTH EXPLORATION OF 'MATHEMATICAL LITERACY' AS A FUNDAMENTAL COMPETENCY** Yujin Seo (Korea Foundation for Science and Creativity)
Special Sharing Group 1-2	
16:30~18:00	**EXPLORING MATHEMATICS LESSONS UTILIZING DIGITAL TOOLS AND MANIPULATIVES** Yujin Seo (Korea Foundation for Science and Creativity)
Special Sharing Group 1-3	
16:30~18:00	**EXAMPLES OF INDUSTRIAL PROBLEM-SOLVING USING MATHEMATICS** Minjung Gim (National Institute for Mathematical Sciences)
Special Sharing Group 1-4	
16:30~18:00	**CHINA-KOREA MATHEMATICS EDUCATION FORUM (PART1): SHAPING THE FUTURE OF MATHEMATICS EDUCATION** Lianghuo Fan (University of Macau)

Special Sharing Groups 2

July 20, Sunday

Special Sharing Group 2-1	
16:30~18:00	**CROSSING OVER EAST ASIAN MATHEMATICS CURRICULA: A FOCUS ON CURRICULUM REFORM** Chaereen Han (Jeonju National University of Education)
Special Sharing Group 2-2	
16:30~18:00	**WRITING GOOD ACADEMIC PAPERS FOR EDUCATIONAL STUDIES IN MATHEMATICS** Vilma Mesa (University of Michigan)
Special Sharing Group 2-3	
16:30~18:00	**CAN A DECOLONIZED MATHEMATICS SECURE NUMERACY FOR ALL?** Allan Tarp (MATHeCADEMY.net)
Special Sharing Group 2-4	
16:30~18:00	**CHINA-KOREA MATHEMATICS EDUCATION FORUM (PART2): SHAPING THE FUTURE OF MATHEMATICS EDUCATION** Qiaoping Zhang (The Education University of Hong Kong)

Special Sharing Groups 3

July 21, Monday	
Special Sharing Group 3-1	
15:30~17:00	**HIGH-QUALITY MATHEMATICS INSTRUCTION: WHAT DO WE MEAN?** Ban Heng Choy (Nanyang Technological University)
Special Sharing Group 3-2	
15:30~17:00	**MATHEMATICAL ARGUMENTATION FOR SUSTAINABILITY: EXPLORING THE CLAIM-EVIDENCE-REASONING (CER) FRAMEWORK IN SOCIO-SCIENTIFIC INQUIRY** Suparat Chuechote (Faculty of Education, Naresuan University)
Special Sharing Group 3-3	
only proceedings	**GLOBAL INSIGHTS AND PERSPECTIVES: EXPANDING THE REACH OF MATHEMATICS EDUCATION JOURNALS IN KOREA** Kyong Mi Choi (University of Virginia)
Special Sharing Group 3-4	
only proceedings	**OUTDOOR MATH MODELING – A UNIQUE CLASSROOM ACTIVITY WITH MATHCITYMAP** Joerg Zender (University of Cologne)

Poster Presentations

Poster Presentation 1	
July 19, Saturday	
PP1-01	**FROM TEACHER NOTICING TO VALUES ALIGNMENT PROCESS: A SYSTEMATIC REVIEW** Haomin Fang (The University of Melbourne, Faculty of Education)
PP1-02	**PROSPECTIVE TEACHER'S VIEW OF GENERATIVE AI IN MATHEMATICS** Yutaka Ohara (Gakushuin University)
PP1-03	**BLENDED LEARNING STATION ROTATION MODEL AND STUDENTS' ENGAGEMENT IN MATHEMATICS LEARNING** Rashidah Vapumarican (CHIJ Kellock, Ministry of Education)
PP1-04	**DEVELOPMENT AND ANALYSIS OF MATHEMATICS MOTIVATION SCALE FOR ELEMENTARY SCHOOL STUDENTS** Yuan-Horng Lin (National Taichung University of Education)
PP1-05	**EVALUATION OF MATHEMATICS CLASSROOM INSTRUCTION IN THE ERA OF ARTIFICIAL INTELLIGENCE** Yiming Cao (Beijing Normal University)
PP1-06	**THE ROLE OF METACOGNITION AND INTELLECTUAL NEED FOR MATHEMATICAL ACTIVITIES** Daiki Kuroda (Gifu Shotoku Gakuen University)
PP1-07	**AFFORDANCE OF PROGRAMMING FOR INTRODUCING TRIGONOMETRIC FUNCTIONS** Chung Man Koo (Hong Kong Taoist Association the Yuen Yuen Institute No.2 Secondary School)
PP1-08	**HOW PRE-SERVICE TEACHERS DEVELOP LESSON PLANS USING CHATGPT** Sunghwan Hwang (Chuncheon National University of Education)
PP1-09	DESIGNING GRAPHING TASKS FROM THE GROUND UP Hwa Young Lee (Texas State University)
PP1-10	**ENHANCING JUNIOR HIGH SCHOOL STUDENTS' SELF-REGULATED LEARNING IN ALGEBRA THROUGH GENERATIVE AI: APPLICATION DEVELOPMENT AND PRELIMINARY FINDINGS** Changhua Chen (National Changhua University of Education)
PP1-11	**TASK MODIFICATION BY PRE-SERVICE MATHEMATICS TEACHERS: AN ANALYSIS FOCUSED ON DEFINITIONS OF GEOMETRIC SIMILARITY** Nam-Hyeok Im (Chungbuk National University)
PP1-12	**AN INVESTIGATION OF THE RELATIONSHIP BETWEEN PISA 2022 TAIWANESE STUDENTS' CURIOSITY AND MATHEMATICAL LITERACY** Wan-Chih Shih (National University of Tainan)
PP1-13	**THE RELATIONSHIP OF STRESS RESISTANCE AND MATHEMATICAL LITERACY: A LATENT CLASS ANALYSIS** Pi-Ying Li (National University of Tainan)
PP1-14	**SUPPORTING LOCALIZED AND CONTEXTUALIZED LEARNING IN BASIC CALCULUS USING BILINGUAL MODULES: A PRELIMINARY INVESTIGATION** Jake Garnace (University of Northern Philippines)
PP1-15	**STUDENT EXPERIENCES AND BARRIERS IN MATHEMATICAL CREATIVITY** Yujin Lee (Kangwon National University)

PP1-16	**STUDENTS' CONCEPTION OF LEARNING DURING PROGRAMMING-RICH MATHEMATICAL ACTIVITIES** Oi-Lam Ng (The Chinese University of Hong Kong)
PP1-17	**A SYSTEMATIC LITERATURE REVIEW OF THE EMPIRICAL STUDIES ON STEAM EDUCATION IN KOREA: 2011-2019** Kyungwon Lee (Seoul National University)
PP1-18	**DEVELOPMENT AND APPLICATION OF AI MATHEMATICS DIGITAL TEXTBOOKS: FOCUSING ON THE KOREAN CASE** Mangoo Park (Seoul National University of Education)
PP1-19	**PROPORTIONAL REASONING IN THE THIRD GRADES OF ELEMENTARY SCHOOL: FOCUSING ON THE COMPOSED UNIT** Hisae Kato (Hyogo University Teacher Education)
PP1-20	**CONSTRUCTION OF THE LEARNING PROCESS OF GRAPH THEORY IN SCHOOL MATHEMATICS: THE EVOLUTION OF THE REPRESENTATION WORLD OF GRAPH** Yuki Tanimoto (Graduate School of Comprehensive Human Sciences, University of Tsukuba)
PP1-21	**CULTIVATING ENTREPRENEURSHIP IN PRESERVICE MATHEMATICS TEACHERS: A CASE OF THE INDUSTRY AND MATHEMATICS EDUCATION COURSE** Kyungwon Lee (Seoul National University)
PP1-22	**PROPOSAL FOR A THEORETICAL FRAMEWORK TO CAPTURE SPONTANEOUS THOUGHTS WHEN CONSIDERING A CONVERSE PROPOSITION** Takeshi Ando (Graduate School of Comprehensive Human Sciences, University of Tsukuba)
PP1-23	**INTERPRETING THE VALUE OF THE TERM "CONSISTENCY" IN CHINA'S NEW MATHEMATICS CURRICULUM STANDARD FOR COMPULSORY EDUCATION** Wenyu Xu (Graduate School of Comprehensive Human Sciences, University of Tsukuba)
PP1-24	**TASK DESIGN TO ENHANCE MATHEMATICAL LEARNING MOTIVATION THROUGH REALISTIC MATHEMATICS EDUCATION** Pui Yan Wong (The Chinese University of Hong Kong)
PP1-25	**THE RELATIONSHIP BETWEEN GENDER AND MATH COMPETENCE BELIEFS THROUGH REFLECTED TEACHER APPRAISAL IN JAPAN AND THE U.S.** Kim Megyesi-Brem (Claremont Graduate University)
PP1-26	**COMMUNICATING WITH METAPHORS: A LONG-TERM CASE STUDY FOR THIRD GRADE ELEMENTARY SCHOOL STUDENTS** Kensuke Koizumi (Yokohama National University)
PP1-27	**A NARRATIVE STUDY ON MATHEMATICS LEARNING INTERACTION BETWEEN PARENTS AND STUDENTS IN LOWER ELEMENTARY SCHOOL** Bo-Myoung Ok (Dankook University)
PP1-28	**A STUDY ON APPLYING IDENTICAL HISTORY OF MATHEMATICS RESOURCES IN DIFFERENT INSTITUTIONS** Yi-Wen Su (University of Taipei)
PP1-29	**EXPLORING AI IN MATHEMATICS EDUCATION FROM THE PERSPECTIVE OF EDUCATIONAL EQUITY AND INCLUSION** Ryoonjin Song (Hanyang University)

Poster Presentation 2	
July 20, Sunday	
PP2-01	**STUDENTS' PERSPECTIVES ON THE RELATIONSHIP BETWEEN QUADRATURE FORMULAE IN ARITHMETIC** Ryuta Tani (Tanaka Gakuen Ritsumeikan Keisho Primary School)
PP2-02	**THE IMPACT OF DIFFERENT PROMPTS ON CREATIVE PERFORMANCE IN PROBLEM POSING TASK** I-Tieh Lin (National Taiwan Normal University)
PP2-03	**A NEW APPROACH OF MATHEMATICAL PROBLEM SOLVING ON THE PREMISE OF USING SCIENTIFIC CALCULATOR: BYOND ALGORITHMIC THINKING/COMPUTATIONAL THINKING** Akio Matsuzaki (Saitama University)
PP2-04	**EXPLORING PEDAGOGICAL DILEMMAS IN AN ITS-BASED MATHEMATICS COURSE** Eun Young Cho (Korean Bible University)
PP2-05	**CHILDREN'S OWN BUNDLE-NUMBERS WITH UNITS MAY REACH THE UNITED NATIONS DEVELOPMENT NUMERACY GOAL** Allan Tarp (Mathecademy.net)
PP2-06	**JOURNAL WRITING IN JUNIOR COLLEGE LEVEL CLASSROOMS: EXPLORING MULTIMODAL EXPRESSIONS AND REFLECTIVE PRACTICES** Nan Dai (Anglo Singapore International School)
PP2-07	**DEVELOPMENT OF A PROGRAMMING LEARNING ENVIRONMENT THAT INDUCES DIALOGUE WITH THE COMPUTER** Shigeki Kitajima (Meisei University)
PP2-08	**IDENTITIES OF STUDENTS' MATHEMATICS TEACHER AS THE STORIES OF OTHERS** Yuriko Kimura (Graduate School of Comprehensive Human Science, University of Tsukuba)
PP2-09	**INVESTIGATING THE IMPACTS AND CHALLENGES OF MATHEMATICAL MODELLING ACTIVITIES ON STUDENTS' LEARNING DEVELOPMENT** Aslipah Tasarib (The National University of Malaysia)
PP2-10	**FROM RULES TO ONTOLOGIES: EVOLVING APPROACHES TO GENERATIVE MULTI-STAGE ASSESSMENT** Jinmin Chung (University Iowa)
PP2-11	**INVESTIGATING NOVICE MIDDLE SCHOOL MATHEMATICS TEACHERS' NOTICING SKILLS IN VIRTUAL TEACHING SIMULATION USING EYE-TRACKING TECHNOLOGY** Yung-Chi Lin (National Tsing Hua University)
PP2-12	**DEVELOPING AN FNIRS ASSESSMENT TOOL FOR STUDENTS' FRACTIONAL STRUCTURE BASED ON APOS THEORY** Doyeon Ahn (Korea National University of Education(KNUE))
PP2-13	**COMPARATIVE STUDY OF THE PERSPECTIVES AND ACCEPTANCE OF UNIVERSITY STUDENTS WITH DIFFERENT EXPOSURES TO GENERATIVE ARTIFICIAL INTELLIGENCE** Ming Fai Chung (The University of Hong Kong)
PP2-14	**TEACHERS' BELIEFS ON MATHEMATICAL PROBLEM- SOLVING WIHTIN PROJECT-BASED LEARNING** Yixuan Liu (Central China Normal University)

PP2-15	**COMPARING THE MATHEMATICAL CREATIVITY OF JUNIOR HIGH SCHOOL STUDENTS IN TAIWAN ACROSS TWO REAL-WORLD CONTEXTS** Lan-Ting Wu (National Taiwan Normal University)
PP2-16	**SEVENTH GRADE ALGEBRAIC WORD PROBLEMS FROM THE PERSPECTIVE OF MATHEMATICAL MODELLING** Alvin Chan (Good Hope School)
PP2-17	**LESSON PLANNING TO TEACH FOR DIVERSITY AND EQUITY** Mi-Kyung Ju (Hanyang University)
PP2-18	**HOW DO KOREAN MIDDLE SCHOOL STUDENTS MAKE VIDEOS RELATED TO MATHEMATICS?** Kyungwon Lee (Seoul National University)
PP2-19	**EXPLORING INQUIRY-BASED LEARNING IN MATHEMATICS TEACHER EDUCATION** Hideyo Makishita (Yamato University)
PP2-20	**PRACTICE LESSONS USING INSTRUCTIONAL VIDEOS** Mahiko Takamura (Tokyo Polytechnic University)
PP2-21	**DEVELOPMENT AND EFFECT ANALYSIS OF AUGMENTED REALITY TOOLS FOR MATHEMATICAL MODELING** Sang Yeon Jo (Seoul National University)
PP2-22	**AN INTRODUCTION TO THE WORLD OF DATA ANALYSIS USING DATA FROM THE ENVIRONMENT** Luis Eduardo Amaya-Briceño (University of Costa Rica)
PP2-23	**AN ANALYSIS OF THE CONTEXT OF PROBABILITY EDUCATION IN JAPANESE MATHEMATICS TEXTBOOKS FROM LOWER SECONDARY SCHOOL TO UPPER SECONDARY SCHOOL: WITH NEGATIVE CAPABILITY AS A BACKGROUND** Hiroto Fukuda (Okayama University of Science)
PP2-24	**FACTORS THAT PROMOTE STUDENTS' SENSE OF BELONGING IN DIVERSE INTRODUCTORY MATHEMATICS CLASSES** Sarah Park (University of Georgia)

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Working Groups

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Working Groups 1

EXPLORING MATHEMATICS LESSONS FOR FOSTERING MATHEMATICAL THINKING

Yujin Seo

DEVELOPMENT OF A TEACHER TRAINING PROGRAM FOR STRENGTHENING AI DIGITAL TEXTBOOK(AIDT) UTILIZATION COMPETENCY

Seo Hyun Ahn, Ho Kyoung Ko, Dennis Odo, Young-suk Lee, Jihwa Noh

BRIDGING MINDS, BUILDING FUTURES:
A RESEARCH COLLABORATION WORKSHOP FOR EMERGING SCHOLARS IN EAST ASIA: PART 1

Kyong Mi Choi, Jennifer M. Suh, Hartono Tjoe, Amanda Meiners, Frackson Mumba, Biyao Liang, Chin Huan, Luona Wang

USING GENERATIVE AI IN SECONDARY MATHEMATICS EDUCATION: DATA ANALYSIS, VISUALIZATION, AND GAMIFICATION

Oh Nam Kwon, Jung Sook Park, Sejun Oh

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EXPLORING MATHEMATICS LESSONS FOR FOSTERING MATHEMATICAL THINKING

Yujin Seo
Korea Foundation for Science and Creativity, Korea, yuzzi@kosac.re.kr

In modern society, the demand for individuals who possess not only basic calculation skills but also critical thinking, communication skills, and creative problem-solving abilities is increasing (WEF, 2016). Accordingly, there is a growing need for innovation in teaching and learning methods that enable students to explore and solve problems independently, thereby fostering their mathematical thinking skills.

This working group aims to analyze various cases of student-centered mathematics lessons and explore effective teaching and learning models that help students develop a deeper understanding of mathematical concepts and cultivate creative problem-solving skills. Through this, we seek to present and discuss practical strategies that can be immediately applied in actual educational settings.

With the recent revision of the mathematics curriculum (November 2022), various efforts have been made to improve teaching methods, particularly focusing on strengthening student-centered inquiry activities. As a result, teaching approaches such as Project-Based Learning (PBL) and Inquiry-Based Learning (IBL) are being actively introduced, with some schools reporting successful case studies. In this workshop, we will analyze the sequence of lesson implementation based on these case studies and derive effective application strategies.

This working group will be conducted as follows (total duration: 90 minutes)

1. Sharing details of the lesson design, implementation, and outcomes of improved teaching methods (10 min × 3 sessions)
   - Concept-Based Learning (CBL), Inquiry-Based Learning (IBL), Mathematics Inquiry Schools, Question-Driven Classrooms, etc.
2. Lesson observation and analysis through a demonstration lesson (Presenter: Teacher, Audience: Students) (15 min)
3. Group-based lesson design reflecting analysis results (30 min)
4. Exchange and discussion of lesson designs to derive effective teaching and learning strategies (15 min)

Through participation in this working group, teachers will gain hands-on experience in designing and implementing student-centered lessons based on curriculum improvements. By independently deriving practical strategies applicable in school settings, they will be better equipped to create effective student-centered learning environments. Additionally, through mutual exchange and discussions, we aim to contribute to enhancing the quality of mathematics education by identifying effective strategies for fostering students' mathematical self-directed learning.

DEVELOPMENT OF A TEACHER TRAINING PROGRAM FOR STRENGTHENING AI DIGITAL TEXTBOOK(AIDT) UTILIZATION COMPETENCY

Seo Hyun Ahn
Ajou University, Korea, aekdl78@ajou.ac.kr

Ho Kyoung Ko
Ajou University, Korea, kohoh@ajou.ac.kr

Dennis Odo
Pusan National University, orea, dmodo@pusan.ac.kr

Young-suk Lee
Pusan National University, Korea, leyoungsuk@hotmail.com

Jihwa Noh
Pusan National University, Korea, nohjihwa@pusan.ac.kr

Background of AI Digital Textbook Utilization

The AI Digital Textbook (AIDT) supports personalized learning tailored to the learner's level and individual characteristics, playing a crucial role in fostering self-directed learning environments (Korea Education and Research Information Service, 2023). AIDT facilitates personalized learning, self-directed learning, and collaborative learning, which necessitates the enhancement of teachers' AI and digital tool utilization competencies (Hong, 2023). Given this background, this study aims to develop training program materials that strengthen teachers' AI and digital competencies to effectively utilize AIDT. Rather than focusing on developing a training model, the study emphasizes the creation of practical teacher training materials (textbooks, learning activities, and assessment tools) that can be directly applied in educational settings, enabling teachers to enhance their instructional effectiveness using AIDT.

Teachers' Digital Literacy and AIDT Utilization Competency

Digital literacy extends beyond basic technological proficiency, encompassing information analysis, critical thinking, and creative problem-solving skills in digital environments (Kwon, 2022). Thus, it is essential to develop practical learning materials and training content to strengthen teachers' AI and digital literacy competencies. This study aims to develop training resources that enable teachers to move beyond merely operating AIDT towards actively analyzing AI-driven educational data, meeting learners' individual needs, and optimizing learning experiences. To achieve this, digital resources, activity sheets, exercises, and hands-on tasks should be included to enhance teachers' AI utilization competencies.

Structure of the AIDT Teacher Training Program Materials

The teacher training materials developed in this study are systematically designed to enhance teachers' AI utilization competencies by equipping them with essential knowledge and skills for AIDT implementation.

1. Understanding the Basic Concepts of AIDT Utilization

- Overview of AI Digital Textbooks: Concepts, Features, and Key Functions
- Understanding Domestic and International AIDT Utilization Cases and Policies
- Theoretical Understanding of AI Digital Textbook Utilization in Education

2. AIDT-Based Instructional Design Competency

- Guidelines on Personalized and Collaborative Learning Strategies Using AIDT
- Development of Subject-Specific AIDT Lesson Plans and Activity Sheets Application of AI-Based Teaching and Learning Design Methodologies
- Overview of AI Digital Textbooks: Concepts, Features, and Key Functions

3. AIDT Data Analysis Competency

- Case Analysis of Data-Driven Personalized Learning and AI-Based Instructional Design
- Learning AI Data Analysis and Feedback Implementation in Classrooms
- Utilizing Learning Data for Personalized Feedback and Achievement Analysis

4. Student Assessment Support Using AIDT

- Implementation of AI-Based Personalized Assessment Tools and Automated Scoring Systems
- Analyzing Students' Learning Data to Assess Achievement and Provide Individualized Feedback
- Using Learning Data for Formative Assessment
- Utilizing Self-Directed Learning Assessment and Reflective Learning Tools through AIDT
- Applying Learning Analytics Techniques to Visualize Student Assessment Results

5. Assessment and Reflection

- Self-Assessment and Checklist for AIDT Utilization in Training
- Developing Teacher Training Journals and Portfolios for Self-Reflection
- Peer Feedback among Teachers

Writing Reports on AIDT Utilization Effectiveness and Outcomes

6. Teacher Research Program for Enhancing AIDT Competency

- Providing Research Design and Implementation Methods for AI-Based Education
- Extracting Improvement Strategies through AIDT-Based Lesson Research and Case Analysis
- Establishing Teacher-Led AI Digital Textbook Research Communities and Sharing Best Practices
- Supporting Research on Educational Innovation and Academic Paper Writing Using AIDT

Expected Outcomes of Teacher Training Program Materials Development

This study aims to develop practical training materials and learning content that can be utilized in teacher training for AI digital textbook competency enhancement. By doing so, the training program transitions from theory-based to practice-oriented learning, enabling teachers to effectively improve their competencies in utilizing AIDT in real educational settings (Hong, 2023). Furthermore, by providing materials that consider various learning formats, this study is expected to contribute to the expansion of AI-based educational environments (Ministry of Education, 2023; Korea Education and Research Information Service, 2023). Future studies should evaluate the effectiveness of these materials and incorporate feedback from the field to ensure continuous improvement (Kwon, 2022).

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BRIDGING MINDS, BUILDING FUTURES: A RESEARCH COLLABORATION WORKSHOP FOR EMERGING SCHOLARS IN EAST ASIA: PART 1

Kyong Mi Choi
University of Virginia, USA, kc9dx@virginia.edu

Jennifer M. Suh
George Mason University, USA, jsuh4@gmu.edu

Hartono Tjoe
Pennsylvania State University, USA, hht1@psu.edu

Amanda Meiners
Northwestern Missouri State University, ameiners@nwmissouri.edu

Frackson Mumba
University of Virginia, USA, fm4v@virginia.edu

Biyao Liang
University of Hong Kong, biyao@hku.hk

Chin Huan
Universiti Sains Malaysia, chinhuan@usm.my

Luona Wang
Huzhou University, 03006@zjhu.edu.cn

Introduction and Objectives

Research collaboration plays a crucial role in fostering academic excellence and innovation. As scholars navigate the challenges of an increasingly interconnected world, the ability to collaborate effectively across institutions and disciplines is essential. The ‘Bridging Minds, Building Futures’ workshop series aims to create a dynamic platform for emerging scholars in East Asia to connect, exchange ideas, and lay the groundwork for future research partnerships.

This proposal outlines the objectives and structure of Part 1 of the workshop, which focuses on establishing connections among participants, identifying common research interests, and setting the foundation for long-term collaboration.

The primary goals of Part 1 of the workshop are:

- To provide a platform for early-career scholars in East Asia to engage in meaningful discussions on research collaboration.
- To introduce participants and their research interests, facilitating potential partnerships.
- To identify shared academic interests and research themes that will guide future collaborative efforts in Part 2 of the workshop.

Target Audience

- Young scholars, postdoctoral researchers, and graduate students from East Asia (including but not limited to China, Japan, South Korea, Taiwan, Hong Kong, Mongolia, and Southeast Asia).
- Experienced scholars with a strong research background who are willing to mentor and guide younger researchers.

Format and Activities

Part 1 of the 'Bridging Minds, Building Futures' workshop will be structured around three key activities:

Opening and Keynote Address

The workshop will begin with a keynote address by a distinguished scholar, who will share insights on the importance of international research collaboration, strategies for building successful academic networks, and the challenges faced by emerging scholars in East Asia. The session will set the tone for the workshop by inspiring participants and highlighting the value of interdisciplinary and inter-institutional partnerships.

Introduction of Participants

Participants will be given the opportunity to introduce themselves, their research backgrounds, and their academic interests. This session will be designed to foster familiarity and encourage meaningful dialogue among attendees.

Identifying Common Interests

Through interactive discussions and guided exercises, participants will explore areas of shared research interest. Small group discussions will allow scholars to engage in deeper conversations, identify potential collaboration themes, and begin conceptualizing future joint research initiatives.

Expected Outcomes

By the end of Part 1, participants will:

- Have a clearer understanding of potential research collaborators within the workshop network.
- Identify at least two or three common research themes that can be further developed in Part 2.
- Establish preliminary research connections that can lead to long-term scholarly collaborations.

USING GENERATIVE AI IN SECONDARY MATHEMATICS EDUCATION: DATA ANALYSIS, VISUALIZATION, AND GAMIFICATION

Oh Nam Kwon

Seoul National University, Korea, onkwon@snu.ac.kr

Jung Sook Park

Junghwa High School, Korea, pjsook9@nate.com

Sejun Oh

Hongik University, Korea, soh@hongik.ac.kr

SNU CRME (Center for Research in Mathematics Education, Seoul National University, Korea) has hosted synchronous online conferences since July 2020, with over 50 webinars and more than 10,000 participants. Additionally, since April 2021, SNU CRME has organized synchronous online PD (professional development) programs for mathematics teachers affiliated with the 17 Metropolitan and Provincial Offices of Education in Korea. The topics of SNU CRME's PD Programs have included new curricula, new digital tools, and mathematical modeling. They are popular among mathematics teachers in Korea and have gained a strong reputation.

With the advancement of genAI (generative artificial intelligence), research has been conducted to analyze the mathematical capabilities of genAI (Kwon et al., 2023, 2024; Oh et al., 2024). There has been ongoing discussion on how to approach genAI from an educational perspective, along with a growing demand for PD programs. Since July 2023, SNU CRME has organized the *ChatGPT Mathematics Classes* PD program four times for mathematics teachers. Among the PD programs offered by SNU CRME, *ChatGPT Mathematics Classes* had high completion rates (See Table 1).

Table 1. The list of ChatGPT mathematics classes PD programs of SNU CRME

Date	Name of PD Programs	Time	Regis-trants	Complemented Participants	Completion Rate
23.07.24.-23.07.26.	*ChatGPT Mathematics Classes Start* (1st cohort)	15	210	202	96.2%
23.09.09.-23.09.23.	*ChatGPT Mathematics Classes Start* (2nd cohort)	15	241	223	92.5%
24.09.21.-24.10.05.	*ChatGPT Mathematics Classes Build-up* (1st cohort)	15	261	236	90.4%
24.11.09.-24.11.23.	*ChatGPT Mathematics Classes Build-up* (2nd cohort)	15	177	146	82.5%

This Working Group (WG) aims to suggest how to design mathematics lessons using GenAI at the secondary school level. In this WG, we introduce cases of secondary school mathematics lessons covered in the *ChatGPT Mathematics Classes* PD programs at the SNU CRME in Korean. This WG is designed for mathematics educators, primary and secondary school teachers, and researchers interested in exploring mathematics teaching and learning strategies using genAI. Prior experience with genAI is not required, but familiarity with digital tools will be beneficial. Since this WG includes activities, participants are encouraged to bring their laptops, but it is not mandatory. Participants can fully engage in activities using smartphones as well. If they have registered for genAI models (e.g., ChatGPT, Gemini, or Claude), the activities of this WG will proceed more smoothly. A paid subscription to genAI models is not required for the activities. The 90-minute presentation is structured as follows: 10 minutes for an overview, 35 minutes each for exploring the use of genAI in high school mathematics through data analysis and discussing ideas on visualization and gamification in middle and high school mathematics, followed by 10 minutes for discussion (See Table 2).

Table 2. The session structure of designing mathematics lessons using genAI

Duration	Content	Coordinator
10 min	Overview of this WG	Oh Nam Kwon (Seoul National University)
35 min	Using genAI in High School Mathematics: Data Analysis	Jung Sook Park (Junghwa High School)
35 min	Ideas for Using genAI in Middle and High School Mathematics: Visualization & Gamification	Sejun Oh (Hongik University)
10 min	Discussion	Oh Nam Kwon (Seoul National University)

In the *Overview of this WG*, we will provide a brief introduction to SNU CRME and discuss the purpose and structure of this WG. In *Using genAI in High School Mathematics: Data Analysis (35 minutes)*, this session will focus on how high school mathematics classes can utilize genAI tools for data analysis. AI-assisted data analysis helps students develop problem-solving and critical thinking skills. Participants will also be introduced to assessment methods, including rubrics that evaluate students' ability to engage with and interpret AI-generated data. In *Ideas for Using genAI in Middle and High School Mathematics: Visualization & Gamification*, this session will highlight how the multimodal capabilities of generative AI-such as visualization tools, interactive graphics, and gamification elements-can be leveraged to enrich mathematics education. We will introduce ideas for integrating AI-generated visual content into lessons to support concepttual understanding. We will explore ways to make math more engaging through game-based learning and interactive AI-driven activities. The *Discussion* will address the potential use of genAI in secondary mathematics classes, as well as the challenges associated with continuous developments of new genAI models. Participants of this WG are given the opportunity to create mathematics tasks using genAI that can be applied to mathematics lessons. This WG offers researchers ideas for designing studies based on mathematics activities using genAI and provides mathematics educators with practical ideas for designing mathematics lessons using genAI.

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MEMO

Working Groups 2

ENHANCING TEACHERS' PRACTICAL TEACHING ABILITIES THROUGH AI-SUPPORTED CLASSROOM INSTRUCTION EVALUATION

Yiming Cao, Yi Wang, Shu Zhang, Wenjun Zhao

A SERIES OF LEARNING ACTIVITIES FOR DEVELOPING THINKING-ORIENTED MATHEMATICAL COMPETENCE

Ying-Hao Cheng, Jian-Cheng Chen, Kai-Lin Yang, Ting-Ying Wang

BRIDGING MINDS, BUILDING FUTURES: A RESEARCH COLLABORATION WORKSHOP FOR EMERGING SCHOLARS IN EAST ASIA: PART 2

Kyong Mi Choi, Jennifer M. Suh, Hartono Tjoe, Amanda Meiners, Frackson Mumba, Biyao Liang, Chin Huan, Luona Wang

DESIGNING MATHEMATICS LESSONS USING GENERATIVE ARTIFICIAL INTELLIGENCE: FOCUSING ON PRACTICES AT THE SECONDARY SCHOOL LEVEL

Oh Nam Kwon, Jungeun Yoon, Kyungwon Lee

KOREA 2025

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The 9th ICMI-East Asia Regional Conference on Mathematics Education

ENHANCING TEACHERS' PRACTICAL TEACHING ABILITIES THROUGH AI-SUPPORTED CLASSROOM INSTRUCTION EVALUATION

Yiming Cao
Beijing Normal University, China, caoym@bnu.edu.cn

Yi Wang
Beijing Normal University, China, yiwang@bnu.edu.cn

Shu Zhang
Beijing Normal University, China, shu.zhang@bnu.edu.cn

Wenjun Zhao
Sichuan Normal University, China, zhaowj6616@sicnu.edu.cn

Discussant: Zsolt Lavicza
Johannes Kepler University Linz, Austria, zsolt.lavicza@jku.at

Session Overview

Results from international educational assessments such as TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment) consistently reveal significant cross-national disparities in student academic achievement, with East Asian students maintaining a leading position in mathematics (Mullis et al., 2020; Schleicher, 2019). Researchers widely acknowledge classroom instruction quality as a critical factor explaining these differences, leading to landmark international comparative studies like the TIMSS video study (Stiger & Hiebert, 1996) and the Learners' Perspective Study (LPS) (Clarke, Keitel, & Shimizu, 2006). These studies systematically uncover characteristics of classroom practices across nations through video coding and qualitative analysis. However, video-based methods of classroom analysis face limitations including single-modal data, low efficiency, and subjective biases (Sun et al., 2020). Recent advancements in artificial intelligence (AI) technologies offer unprecedented opportunities to overcome these limitations.

Classroom instruction quality serves as an external manifestation of teachers' practical teaching abilities, and enhancing these abilities is fundamental to ensuring instructional excellence. Against this backdrop, this symposium focuses on leveraging AI technologies to establish comprehensive, scientific, and efficient classroom instruction evaluation systems for improving teachers' practical teaching abilities.

Three researchers will present their recent work regarding this topic. First, Wenjun Zhao will talk about how to redefine AI-supported classroom instruction evaluation frameworks by integrating multi-modal data. Second, Yi Wang will introduce an AI-driven intelligent classroom instruction evaluation system and demonstrating its applications. Lastly, Shu Zhang will illustrate the construction of an "researcher-AI-teacher" collaborative improvement mechanism through two case studies, showcasing how data-driven approaches optimize teaching practices.

The working group adopts the format of presentations, interval Q&A sessions, and final discussion session. The first hour is evenly divided among the three presentations with each presentation taking 20 minutes including 5minutes Q&A . The remaining 30 minutes will include comments from the discussant and freely discussion with the audience.

Below are the abstracts of the three presentations.

Presentation 1:
An Indicator System for Assessing Mathematics Classroom Instruction Quality Based on Multimodal Data

Wenjun ZHAO, Yiming CAO

This study constructed an indicator system for assessing mathematics classroom instruction quality that covers the dimensions of behavior, language, and emotions. The integration of these three dimensions enables a multi-modal evaluation of classroom instruction quality. Indicators of behaviors include explanation, questioning, responding, and feedback; indicators of language oriented towards the development of students' key competencies; indicators of classroom emotion include classroom emotion such as positive, negative and neutral, and teacher-student attention.

Presentation 2:
Intelligent Evaluation System for Mathematics Classroom Instruction Quality and its Application

Yi WANG, Yiming CAO

In collaboration with a technology company, we have constructed an Intelligent Evaluation System for Mathematics Classroom Instruction Quality. Through the integration of computer vision, natural language processing (NLP), and affective computing, it creates a comprehensive evaluation environment suitable for mathematics classrooms across various educational settings. This system has broad applications in the field of education, encompassing Teacher Training and Development, Classroom Quality Assurance for schools and educational institution, Educational Research, and Policy Making.

Presentation 3:
Building a learning community with AI-teacher-researcher: A case study of two teachers' reflections and learning

Shu ZHANG

This study proposes and examines a novel triangular-structured learning community that integrates human educational researchers, AI teaching analysts (AI-TAs), and in-service teachers to foster collaborative reflection and pedagogical growth. Through a two-month case study involving two secondary mathematics teachers, we employed design-based research methodologies to investigate how this triangular dynamic facilitates professional learning.

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A SERIES OF LEARNING ACTIVITIES FOR DEVELOPING THINKING-ORIENTED MATHEMATICAL COMPETENCE

Ying-Hao Cheng

University of Taipei, Taiwan, yinghao.cheng@uTaipei.edu.tw

Jian-Cheng Chen

National Taipei University of Education, Taiwan, jiancheng@mail.ntue.edu.tw

Kai-Lin Yang

National Taiwan Normal University, Taiwan, kailin@ntnu.edu.tw

Ting-Ying Wang

National Taiwan Normal University, Taiwan, ting@abel.math.ntnu.edu.tw

Learning Goals and Activities in Mathematics Education

Students' learning goals have expanded from merely acquiring knowledge to developing the competences necessary for future life. Mathematical competence encompasses several aspects: understanding fundamental mathematical knowledge, applying mathematics to solve real-world problems, fostering a positive attitude toward mathematics, and cultivating a habit of lifelong learning (Yang, et al., 2021). OECD (2018) advocates that mathematical competence and thinking skills are mutually developed, such as creative thinking, reflective thinking, critical thinking, systematic thinking, etc.

There have been numerous learning activities designed to enhance students' mathematical competence and thinking skills. These include mathematical conjecturing activities (MCA) that focus on reasoning and argumentation, inquiry-based mathematics activities (IMA) that promote active exploration and discovery, mathematics-grounded activities (MGA) that foster motivation and the development of conceptual images, and mathematical modeling activities (MMA) that highlight the connection between mathematics and real-world applications.

Gaps between Ideal and Practical Mathematics Education

Research has identified various activities that can enhance students' mathematical competence, such as mathematical conjecturing and modeling activities. These ideal learning activities have specific criteria, including mathematical content, learning objectives, instructional methods, learning processes, assessment techniques, and teaching duration. If mathematics teachers wish to incorporate specific activities into their classroom instruction, they must address the inconsistency between the ideal specifications of these activities and the realities of classroom teaching. Consequently, a significant number of mathematics teachers are reluctant to implement such activities, particularly due to the prevailing teaching culture, which is often influenced by the emphasis on entrance examination preparation.

The Need for a Series of Learning Activities as to Each Mathematical Topic

It is essential to consider the practical needs of teachers when developing teaching activities aimed at enhancing students' mathematical competency. Generally, mathematics teaching and learning activities can be divided into three phases: initiating, sustaining, and concluding mathematical activities (Johnston-Wilder and Mason, 2004). These phases correspond to the goals of concept inspiration and formation, connection and deepening, and integration and extension (knowing and applying), respectively. When teaching activities also take into account mathematical perspectives, dispositions (viewing), and thinking skills (learning), they contribute to the development of mathematical competence in knowing, applying, viewing, and learning (Yang et al., 2021). Based on this, instructional design must incorporate a variety of appropriate learning activities tailored to different developmental phases to gradually cultivate students' thinking-oriented mathematical competencies.

Aims and Activities in the Working Group

Thinking-oriented mathematical competence refers to mathematical competence with thinking skills (such as creative thinking skills). What types of mathematics learning activities are suitable for fostering this competence, and how can they be developed? The aim of this working group is to utilize a series of learning activities designed by our project, which include MGA, MCA, IMA, and MMA, as examples to guide participants in discussing these issues. The schedule for this working group is presented in Table 1.

Table 1. Schedule for the working group

Phases	Description
Introduction (5 mins)	Introduction of the background of the working group
The four presentations (25 mins)	Mathematics-grounding activities (K.-L. Yang) Mathematical conjecturing activities (Y.-H. Cheng) Inquiry-based mathematics activities (J.-C. Chen) Mathematical modelling activities (T.-Y. Wang)
Group activity (35 mins)	Working on guiding questions based on the four presentations 1. Which thinking skills are needed to learn mathematics and why? 2. Which thinking skills can be developed as learning mathematics and why? 3. Which learning activities are suggested to develop thinking-oriented mathematical competence? 4. Which ways can be used to integrate thinking skills in learning activities?
Discussion (25 mins)	Discussion of group results

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BRIDGING MINDS, BUILDING FUTURES: A RESEARCH COLLABORA-TION WORKSHOP FOR EMERGING SCHOLARS IN EAST ASIA: PART 2

Kyong Mi Choi
University of Virginia, USA, kc9dx@virginia.edu

Jennifer M. Suh
George Mason University, USA, jsuh4@gmu.edu

Hartono Tjoe
Pennsylvania State University, USA, hht1@psu.edu

Amanda Meiners
Northwestern Missouri State University, ameiners@nwmissouri.edu

Frackson Mumba
University of Virginia, USA, fm4v@virginia.edu

Biyao Liang
University of Hong Kong, biyao@hku.hk

Chin Huan
Universiti Sains Malaysia, chinhuan@usm.my

Luona Wang
Huzhou University, 03006@zjhu.edu.cn

Introduction and Objectives

Following the successful foundation laid in Part 1 of the Bridging Minds, Building Futures workshop, Part 2 aims to deepen research engagement, foster mentorship, and develop concrete collaboration plans among emerging scholars in East Asia. This phase of the workshop will provide structured sessions for scholars to refine their research ideas, receive guidance from senior academics, and create actionable plans for future joint projects.

The primary goals of Part 2 are:

- To facilitate discussions on specific research interests through focused breakout sessions.
- To provide mentorship and networking opportunities for emerging scholars.
- To develop concrete plans for collaborative research projects that participants can pursue beyond the workshop.

Format and Activities

Part 2 of the Bridging Minds, Building Futures workshop will be structured around four key activities:

Breakout Sessions Based on Interests

Building on the research themes identified in Part 1, participants will join breakout sessions based on shared academic interests. These sessions will allow scholars to engage in focused discussions, refine research ideas, and explore potential collaborative projects. Facilitators will guide discussions to ensure that groups work toward developing tangible research concepts.

Mentorship & Networking Session

To support the professional growth of emerging scholars, this session will bring in senior academics to offer mentorship and career guidance. Through one-on-one and small group discussions, participants will receive valuable insights on research collaboration, academic publishing, and navigating the challenges of an academic career. This session will also serve as a platform for networking with experienced scholars and potential research partners.

Future Collaboration Plan

In this session, each breakout group will work on formulating a structured plan for future collaboration. This will include defining research objectives, outlining methodologies, identifying potential funding sources, and establishing a timeline for joint projects. The goal is for each group to leave with a clear roadmap for their collaborative efforts beyond the workshop.

Closing Session

The workshop will conclude with a reflection session where participants will share their key takeaways and commitments to future collaboration. Organizers will summarize the outcomes of the workshop and discuss possible follow-up initiatives to support continued scholarly engagement.

Expected Outcomes

By the end of Part 2, participants will:

- Have well-defined research groups based on shared academic interests.
- Gain mentorship and professional advice from senior scholars.
- Develop concrete research collaboration plans with actionable next steps.
- Strengthen their academic network for future interdisciplinary and cross-institutional research.

Conclusion

Part 2 of the Bridging Minds, Building Futures workshop will transform initial connections into structured research collaborations. By providing a platform for focused discussions, mentorship, and concrete planning, this phase ensures that emerging scholars move beyond networking to actively engage in meaningful academic partnerships. This initiative will contribute to building a strong and sustainable research community in East Asia, empowering scholars to advance knowledge and innovation through collaboration.

DESIGNING MATHEMATICS LESSONS USING GENERATIVE ARTIFICIAL INTELLIGENCE: FOCUSING ON PRACTICES AT THE SECONDARY SCHOOL LEVEL

Oh Nam Kwon
Seoul National University, Korea, onkwon@snu.ac.kr

Jungeun Yoon
Incheon Hyosung High School, Korea, yoonhoho1004@snu.ac.kr

Kyungwon Lee
Dankook University Middle School, Korea, kyungwon.lee.snu@gmail.com

SNU CRME (Center for Research in Mathematics Education, Seoul National University, Korea) has hosted synchronous online conferences since July 2020, with over 50 webinars and more than 10,000 participants. Additionally, since April 2021, SNU CRME has organized synchronous online PD (professional development) programs for mathematics teachers affiliated with the 17 Metropolitan and Provincial Offices of Education in Korea. The topics of SNU CRME's PD Programs have included new curricula, new digital tools, and mathematical modeling. They are popular among mathematics teachers in Korea and have gained a strong reputation.

With the advancement of genAI (generative artificial intelligence), research has been conducted to analyze the mathematical capabilities of genAI (Kwon et al., 2023; Oh et al., 2024). There has been ongoing discussion on how to approach genAI from an educational perspective, along with a growing demand for PD programs. Since July 2023, SNU CRME has organized the *ChatGPT Mathematics Classes* PD program four times for mathematics teachers. Among the PD programs offered by SNU CRME, *ChatGPT Mathematics Classes* had high completion rates (See Table 1).

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24.11.09.-24.11.23.	*ChatGPT Mathematics Classes Build-up* (2nd cohort)	15	177	146	82.5%

This Working Group (WG) aims to suggest how to design mathematics lessons using genAI at the secondary school level. In this WG, we introduce cases of secondary school mathematics lessons covered in the *ChatGPT Mathematics Classes* PD programs at the SNU CRME in Korean. This WG is designed for mathematics educators, primary and secondary school teachers, and researchers interested in exploring mathematics teaching and learning strategies using genAI. Prior experience with genAI is not required, but familiarity with digital tools will be beneficial. Since this WG includes activities, participants are encouraged to bring their laptops, but it is not mandatory. Participants can fully engage in activities using smartphones as well. If they have registered for genAI models (e.g., ChatGPT, Gemini, or Claude), the activities of this WG will proceed more smoothly. A paid subscription to genAI models is not required for the activities. The 90-minute presentation is structured as follows: 10 minutes for an overview, 35 minutes each for designing middle and high school mathematics lessons, and 10 minutes for discussion (See Table 2).

Table 2. The session structure of designing mathematics lessons using genAI

Duration	Content	Coordinator
10 min	Overview of this WG	Oh Nam Kwon (Seoul National University)
35 min	Designing high school mathematics lessons using genAI	Jungeun Yoon (Hyosung High School)
35 min	Designing middle school mathematics lessons using genAI	Kyungwon Lee (Dankook University Middle School)
10 min	Discussion	Oh Nam Kwon (Seoul National University)

In the *Overview of this WG*, we will provide a brief introduction to SNU CRME and discuss the purpose and structure of this WG. In *Designing High School Mathematics Lessons*, we will introduce a case study of flipped learning (e.g., Yoon et al., 2023) and error analysis lessons in Korean high schools that incorporate genAI into teaching mathematics. This session will cover the required resources for flipped learning and error analysis lessons, while also proposing methods for generating resources including teaching and learning materials, assessment rubric, and basic information for the use of genAI. In *Designing Middle School Mathematics Lessons*, we will present practical cases of mathematics classes in Korean middle schools that utilize genAI and explore lesson design strategies. Specifically, we will introduce Korean middle school mathematics lessons on error analysis, problem posing, mathematical modeling, and data analysis using genAI. This session includes activities for error analysis and problem posing, as well as an introduction to strategies on creating relevant mathematical tasks. The *Discussion* will address the potential use of genAI in secondary mathematics classes, as well as the challenges associated with continuous developments of new genAI models, the evolving role of teachers, and ethical issues such as informed consent and privacy, data bias, and issues related to academic integrity, including plagiarism and overreliance.

Participants of this WG are given the opportunity to create mathematics tasks using genAI that can be applied to mathematics lessons. This WG offers researchers ideas for designing studies based on mathematics activities using genAI and provides mathematics educators with practical ideas for designing mathematics lessons using genAI.

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MEMO

Working Groups 3

TEACHING MATHEMATICS FOR SOCIAL JUSTICE : CASES FORM KOREA

Jaehoon Shim, Mangoo Park

MATHEMATICAL HABITS OF MIND: A FRAMEWORK FOR UNDERSTANDING AND SUPPORTING POSITIVE DISPOSITONS TOWARD MATHEMATICS LEARNING

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KOREA 2025

EARCOME9

The 9th ICMI-East Asia Regional Conference on Mathematics Education

TEACHING MATHEMATICS FOR SOCIAL JUSTICE : CASES FORM KOREA

Jaehoon Shim
Seoul Inheon Elementary School, Korea, dkfrtw16@gmail.com

Mangoo Park
Seoul National University of Education, Korea, mpark29@snue.ac.kr

Introduction

Mathematics is often seen as a neutral and abstract discipline(Ernest, 2015), yet its teaching can play a vital role in promoting social justice(Gutstein, 2016; Skovsmose, 2023; Wager & Stinson, 2012). By integrating real-world issues such as inequality, resource distribution, and data literacy into mathematics education, educators can empower students to critically analyze and address societal challenges(D'Ambrosio, 1999; Osler, 2007; Park, 2019). This paper explores the necessity of teaching mathematics for social justice, focusing on its potential to bridge educational and social gaps. Drawing on examples from South Korea, it highlights how justice-oriented mathematics education can inspire change in both classrooms and communities.

The Necessity of Teaching Mathematics for Social Justice

Teaching mathematics for social justice is essential to transform education into a tool for equity and empowerment(Bartell et al., 2024). Traditional mathematics education often prioritizes abstract skills over contextual understanding, leaving students disconnected from its broader implications (Skovsmose, 2023). By contrast, a justice-oriented approach enables students to use mathematics to interpret and challenge societal inequities, such as income disparity or resource allocation (Gutstein, 2016; Shim & Park, 2022, 2024). This shift is particularly crucial in addressing educational disparities, as it engages marginalized students whose experiences are often sidelined in conventional curricula (Aguirre et al., 2024). Moreover, it fosters critical thinking and agency, equipping learners to question systemic issues rather than passively accept them (Barbosa, 2006, 2009; Skovsmose, 2023). In a globalized world where data drives decision-making, mathematical literacy becomes a gateway to civic participation and social change (D'Ambrosio, 1999; Frankenstein, 2001; Gutstein, 2016; OECD, 2023; Skovsmose, 1998). Without this focus, mathematics risks remaining an elitist discipline, accessible only to those already privileged(Friere, 1970). Thus, integrating social justice into mathematics education is not merely an option but a necessity to cultivate informed, engaged citizens capable of reshaping an unequal society.

In this context, Bartell et al. (2024) argue that focusing solely on mathematical content creates a disconnect between the subject, students' passions, and their lived experiences. They emphasize that mathematics education should heighten awareness of social injustices and inspire action, highlighting five key purposes: building an informed society, connecting mathematics to students' cultural and community histories, linking it to other school subjects, empowering students to address real-world challenges, and helping them value mathematics as a tool for social change(Bartell et al., 2024, p. 19). These principles underscore why teaching mathematics for social justice is not just an option but a necessity to cultivate informed, engaged citizens capable of reshaping an unequal society.

Cases from South Korea

South Korea provides a compelling context for exploring how teaching mathematics for social justice can be implemented in practice. With its highly competitive education system (e.g., high rates of repeat students, excessive private education costs) and rapid economic development, the country faces challenges such as urban-rural disparities and socioeconomic inequality (e.g., polarization of housing prices, differences in infrastructure, income disparity), and recent political issues (e.g., martial law, presidential impeachment). Addressing these issues through the lens of mathematics can offer students enriching experiences. A justice-oriented approach aligns with the human resource goals presented in the recently revised Korean curriculum, which advocates for 'self-directed individuals with creativity and inclusiveness' (Ministry of Education, 2022, p. 4), and expands the purpose of mathematics education beyond simple calculations to include the acquisition of rational thinking encompassing social awareness and equity.

The following presents two case studies of mathematics lessons designed for social justice, which we conducted (Shim & Park, 2022, 2024). The first case was implemented from November to December 2021 with fourth-grade students. Titled "Reading and Writing Food with Mathematics," the lesson involved students measuring leftover food from school lunches and representing the data with line graphs (see Figure 1). Through this activity, students not only learned to construct line graphs but also engaged in discussions about environmental issues, the cost of food waste disposal, and global food security challenges. The second case took place in May 2024 with sixth-grade students, under the theme "Determining My Own Living Allowance" (see Figure 2). Students created their own models for a living allowance, compared them with real-world models, and critically discussed the process of forming mathematical models and their practical implications.

Figure 1. Leftover food amount from monday to friday and the students' line graph

Year	Amount of Basic Living Allowance
2015	(Household Median Income × 28%) − (Household Median Income)
2016	(Household Median Income × 29%) − (Household Median Income)
2017 ~ 2023	(Household Median Income × 30%) − (Household Median Income)
2024	(Household Median Income × 32%) − (Household Median Income)
▪ Household Median Income: Average income of the entire household	

Figure 2. South Korea basic living allowance payment model

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MATHEMATICAL HABITS OF MIND: A FRAMEWORK FOR UNDERSTANDING AND SUPPORTING POSITIVE DISPOSITONS TOWARD MATHEMATICS LEARNING

Jihwa Noh
Pusan National University, Korea, nohjihwa@pusan.ac.kr

Elena Prieto-Rodriguez
University of Newcastle, Australia, elena.prieto@newcastle.edu.au

Dongjo Shin
Pusan National University, Korea, djshin@pusan.ac.kr

Hye-Young Byeon
Pusan National University, Korea, bhyoung17@pusan.ac.kr

Focus

This Working Group (WG) will explore the concept of Mathematical Habits of Mind (MHoM) as a potentially more effective framework for understanding students' engagement, persistence, and attitudes toward mathematics. While traditional models focus on affective characteristics—such as motivation, beliefs, attitudes, and emotions—this WG seeks to examine whether MHoM provides a more holistic and actionable approach to assessing and fostering positive dispositions in mathematical learning. Given the evolving discourse around mathematical thinking and problem-solving, the session aims to build a shared understanding and develop collaborative research directions in this promising field.

Objectives

1. Conceptual Clarification: Define and refine the construct of Mathematical Habits of Mind, drawing on existing literature and participants' experiences.
2. Comparative Analysis: Analyze how MHoM aligns with or diverges from classic affective components such as attitudes, motivation, and beliefs.
3. Assessment Potential: Discuss whether MHoM offers a more robust framework for diagnosing areas where students need support in developing positive mathematical dispositions.
4. Collaborative Research Directions: Develop potential research questions and methodologies for future collaborative studies.

Structure

The WG will consist of three interactive sessions, each structured to encourage active participation, collaboration, and the exchange of ideas:

Session 1: Defining Mathematical Habits of Mind

- Brief presentation on current definitions and frameworks in the literature.
- Small group discussions: Participants will share experiences and perspectives on what constitutes MHoM.
- Group synthesis: Collective development of a working definition

Session 2: Comparing MHoM with Traditional Affective Components

- Group work comparing MHoM with constructs such as motivation, self-efficacy, and attitudes.
- Group synthesis: Examples where MHoM could offer alternative insights.

Session 3: Toward a New Assessment Framework

- Discussion on the potential of MHoM as an assessment tool.
- Collaborative brainstorming: Designing sample assessment tools or indicators for MHoM.
- Identifying areas for future research collaboration.

Expected Outcomes

- A collaboratively developed framework for conceptualizing Mathematical Habits of Mind.
- A comparative analysis document detailing key similarities and differences between MHoM and traditional affective measures.
- A list of proposed research questions and potential joint projects for future collaboration.

Conclusion

This WG aims to foster meaningful dialogue and collaboration among mathematics education researchers interested in refining how we conceptualize and assess mathematical thinking and dispositions. By focusing on Mathematical Habits of Mind, participants will collectively explore innovative pathways to support students' engagement and success in mathematics.

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POETIC METHODS IN MATHEMATICS EDUCATION

Pauline Tiong

National Institute of Education, Singapore, pauline.tiong@nie.edu.sg

Aehee Ahn

Massey University, New Zealand, a.ahn@massey.ac.nz

Sheena Tan

Simon Fraser University, Canada, smtan@sfu.ca

Background

This working group continues the work of the POEME group, established at the 46th Conference of the Psychology of Mathematics Education (PME) in 2023 (Staats & Helme, 2023). At previous PME Working Group sessions, the POEME group has focused on how poetic methods provide new ways of analysing qualitative data by attending to the structure of utterances (such as the syntactic, lexical and sound features) and the relationships between them. Specifically, the poetic method, which stems from linguistics anthropology, was first introduced into mathematics education research by Sue Staats (2008), based on the poetic function of verbal communication put forth by Jakobson (1960). Grounded on human's tendency to repeat or rephrase each other, the poetic method examines how recurring or parallel lines contribute to the (mathematical) meaning constructed within a (mathematics) discourse that may not be expressed explicitly through the definitions of words alone (Staats, 2008). Staats (2021) further argues how the poetic method allows for a "shift away from a static, objectified, utilitarian view of mathematical discourse to a process-oriented and generative one" (p. 2).

Notably, the poetic method as a way of analysing data affords for the noticing of different mathematical voices (e.g., meanings or arguments) present (Staats, 2008, 2017, 2021). This noticing can be extended to gestures and emotions as additional layers inherent in human communication and interaction (Hare, Helme & Staats, 2024). Moreover, poetic structures present a way to engage with dynamic processes of data interpretation, challenging traditional notions of transcription and also rigor and objectivity (Ohito & Nyachae, 2019). The method fosters researchers' reflexivity, acknowledging that understanding is shaped through dynamic interactions with data. Thus, as part of this ongoing series of poetic discussions, one aim of this working group is to extend the dialogue on poetic approaches in mathematics education research; and to build a network of scholars interested in these methods.

This workshop seeks to provide participants with an opportunity to experiment with poetic structures using different types of discourse data and to explore the possible interpretations that emerge from the data. Through collaborative analysis, we will also reflect on how each individual may generate (similar or different) poetic structures from their own noticing and share insights into the process. The discussion will focus on refining the method of poetic inquiry collaboratively and examining its value and relevance in mathematics education research.

Goals of the Working Group

Participants in this working group will consider the following questions:

1. What are the underlying assumptions and values of poetic methods in mathematics education research?
2. What research phenomena could be investigated through poetic methods?

Activities and Timeline

In this working group, we will offer various types of mathematical discourses (e.g., interview transcripts, written texts, and video transcripts) for participants to have hands-on experience in generating poetic structures based on their perspectives, purposes, or interest. We will also share some possible poetic analysis of the data.

- Introduction by organisers: Outlining poetic inquiry and goals of the working group (15 mins)
- Working with the data in groups to construct a poem (30 mins)
- Sharing of groups' poems and discussion (30 mins)
- Consolidation and future plans (15 mins)

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REPLACING STEAM WITH STEEM TO ALSO INCLUDE ECONOMICS

Allan Tarp
MATHeCADEMY.net, Denmark, Allan.Tarp@gmail.com

Yujin Lee
Kangwon National University, Korea, YLEE@kangwon.ac.kr

From STEM over STEAM to STEEM

STEM integrates mathematics with its roots in science, technology and engineering, all using formulas from algebra and trigonometry to pre-dict the behavior of predictable physical quantities, and to model unpredictable quantities by scenarios. Statistics 'post-dicts' unpredictable quantities by setting up probabilities for future behavior, using fact or fiction numbers as median and fractals or average and deviation. Including economics in STEM opens the door to statistics also. Art may be an appetizer, but not a main course since to play a core role in STEM, geometry and algebra should be together always and never apart. Art is a sugar coating making the pill go down but does not make the pill more digestible. STEM thus may be extended to STEAM to make it more appealing and motivating, but extending STEM to STEEM will increase the understanding of the nature of numbering and calculating to meet the fourth of the UN sustainable development goals saying that within 2030 all youth and most adults should possess numeracy. Which will enable a communicative turn in the number-language as the one that took place within the word-language around 1970.

Economics Gives a Fundamental Understanding of Numbers and Calculations in Primary School

The basic meanings of geometry and algebra show that they are both rooted in economics. In Greek, geometry means to measure earth, and in Arabic, algebra means to reunite numbers, so they have a common root in the basic economic question "How to divide the earth and what it produces?" As a hunter-gatherer you need not tell the different degrees of many apart but as a farmer you do since here you produce to a market to survive and need to be numerate to answer the question "How many here?". This immediately leads to the answer "That depends on the unit." Economics thus begin at once by reusing the number-names when using bundling to count.

The romans unsystematically gave names to the bundles 5s, 10s, 50s, 100s, 500s and 1000s. This worked well for administrative addition and subtraction jobs but not for multiplication. So, when German silver reopened the trade between India and Renaissance Italy, Hindu-Arabic numbers named only the unbundled, the bundles, the bundle of bundles (BB or B^2), the bundle-bundle-bundle (BBB or B^3), etc. Typically, ten was used as the bundle-size, but also dozens and scores, 12s and 20s.

At a market you sell goods in bundles with different units, e.g., 2 3s. But the buyer may want to have 5s or trade 4 per 5 or pay 4$ per 5. So, changing units becomes a core job: '2 3s = ? 5s', and '6 7s = ? tens', and '3 tens = ?6s'. Likewise, when changing the units for length, weight, volume, and currency, And, when changing from the quantity to the price. Here, Renaissance Italy used 'regula detri', the rule of three. Asking "With the per-number 2$ per 3kg, what is the price for 9kg?", first they arranged the three numbers with alternating units: '9kg, 2$, 3kg'. Then they found the answer by multiplying and dividing: 9*2/3 = 6$. Today we use proportionality and say 9kg = (9/3)*3kg = (9/3)*2$ = 6$ when using the core linear recount-formula T = (T/B)*B, coming from recounting 8 in 2s as 8 = (8/2)*2.

Before school, children use bundle-numbers with units as 2 3s and 4 5s thus telling apart counting numbers in time as 2 and 4 from bundle-numbers in space as 3s and 5s. The school does not do so and insists that 1+1 = 2, which the children question by using an open and a closed V-sign to show that 2 1s and 1 2s add to 1 4s and not to 3 3s as the school says. Then they point out that the three core unit-change questions lead to a division table, a multiplication table, and to solving equations by recounting. And that adding 2 3s and 4 5s next-to as 8s is adding areas found by calculus. And that recounting the height in the base in 4 5s is trigonometry giving $\pi = n*\tan(180/n)$ for n high enough. They thus learn core math by counting and recounting before adding when beginning with economics.

Macroeconomics and Microeconomics in Middle School and High School

Later, macroeconomics describes households and factories exchanging salary for goods on a market in a cycle having sinks and sources: savings and investments controlled by banks and stock markets; tax and public spending on investment, salary and transferals controlled by governments; and import and export controlled by foreign markets experiencing inflation and devaluation. Proportionality and linear formulas may be used as first and second order models for this economic cycle, using regression to set up formulas and spreadsheets for simulations using different parameters.

And, microeconomics describes equilibriums in individual cycles. On a market, shops buy and sell goods with a budget for fixed and variable costs, and with a profit depending on the volume sold and the unit-prices, all leading to linear equations. In the case of two goods, optimizing leads to linear programming. Competition with another shop leads to linear Game Theory. Market supply and demand determine the equilibrium price. Market surveys lead to statistics, as does insurance. In the households, spending comes from balancing income and transferals with saving and tax. In a bank, income comes from simple and compound interest, from installment plans as well as risk taking. On the stock market, courses fluctuate. Governments must consider quadratic Laffer-curves describing a negative return to a tax-raise. To avoid units, factories use variations of Cobb-Douglas power elasticity production functions for modeling.

The Working Group Program

In the working group we will experience how basic economic questions in primary school lead to a somewhat different mathematics that uses bundle-numbers with units, which need to change units before being traded. This allows core mathematics as linearity and calculus to grow from the two questions '2 3s is how many 5s?', and '2 3s + 4 5s total how many 8s?' This roots the proportionality recount-formula T = (T/B)*B, as well as calculus when adding globally and locally constant per-numbers. Finally, examples from the other STEM areas will be considered under the light of bundle-numbers with units, and the difference between fact, fiction and fake models will be discussed.

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Special Sharing Groups

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The 9th ICMI-East Asia Regional Conference on Mathematics Education

IN-DEPTH EXPLORATION OF 'MATHEMATICAL LITERACY' AS A FUNDAMENTAL COMPETENCY

Yujin Seo
Korea Foundation for Science and Creativity, Korea, yuzzi@kosac.re.kr

Mathematical literacy was designated as one of the fundamental competencies in the 2022 Revised Curriculum (November 2022) and has been emphasized as a core skill for nurturing future talents equipped with mathematical thinking and problem-solving abilities. Furthermore, in the 4th Comprehensive Plan for Mathematics Education (December 2024), the importance of mathematical literacy has been re-emphasized, leading to stronger policy initiatives to enhance its development.

However, there remains a gap in understanding the concept and scope of mathematical literacy among educators and policymakers (Korea Institute for Curriculum and Evaluation, 2020), making it difficult to implement effective education policies and support programs. The ongoing debate continues on whether mathematical literacy refers solely to basic arithmetic skills or if it encompasses broader competencies such as logical reasoning, problem-solving, and data utilization skills. Given this context, clarifying the conceptual definition of mathematical literacy and reaching a social consensus on its meaning and application scope has become an urgent issue.

This special sharing groupaims to bring together educators, as key implementers of policy initiatives, to explore and establish a comprehensive understanding of mathematical literacy from various perspectives. Through in-depth discussions, we seek to identify more effective educational and policy directions that enhance teachers' understanding of the intrinsic value of mathematical literacy and its practical applicability in both the classroom and policy development.

While there is a general consensus in the education sector on the importance of mathematical literacy, a unified definition and approach to teaching it have yet to be established. Some curricula limit mathematical literacy to basic arithmetic and foundational mathematical skills, while others adopt a broader interpretation that includes data analysis, logical reasoning, and problem-solving competencies. As a result, the methods of applying mathematical literacy in educational settings vary, making it difficult to establish a consistent policy direction. Furthermore, adequate instructional materials and training programs to support teachers in effectively fostering mathematical literacy have not yet been sufficiently developed. To address these issues, it is crucial to establish a clear definition of mathematical literacy that reflects teachers' perspectives and to develop policies that provide meaningful support.

Key Discussion Topics of This Special Sharing Group

1. Conceptual Analysis of Mathematical Literacy– Reviewing definitions of mathematical literacy from previous studies (10 min)
2. Educational Perspectives & Case Sharing– Discussing teachers' perceptions of mathematical literacy and sharing real-life classroom applications (20 min)
3. Policy Direction Discussion– Exploring policy directions for strengthening mathematical literacy and conducting in-depth group discussions on practical support strategies (15 min)

4. Practical Classroom Applications– Discussing effective instructional strategies and the development of teaching and learning materials to enhance mathematical literacy in lessons (20 min)
5. Exchange of Discussion Outcomes– Deriving meaningful educational implications through mutual exchange of insights (15 min)

Through participation in this special sharing group, teachers are expected to develop a clearer understanding of the concept and scope of mathematical literacy. Additionally, by incorporating teachers' insights into the policy-making process, it will be possible to establish more practical and effective educational policies tailored to real classroom needs. Furthermore, by reaching a broader social consensus on the definition of mathematical literacy through diverse discussions, this initiative will contribute to fostering future talents equipped with mathematical thinking and problem-solving skills, which are essential in the evolving global landscape.

EXPLORING MATHEMATICS LESSONS UTILIZING DIGITAL TOOLS AND MANIPULATIVES

Yujin Seo
Korea Foundation for Science and Creativity, Korea, yuzzi@kosac.re.kr

With the decline in the school-age population and the rise of the digital transformation era, major countries worldwide are implementing educational reform policies to nurture future talent. These initiatives focus on enhancing students' access to online learning content and tools while providing personalized, optimized learning environments (National Assembly Research Coordination Council, 2024). In response, South Korea's 2022 revised mathematics curriculum emphasizes the use of online learning environments and technological tools, introducing play-based and game-based learning as new teaching and learning strategies. To realize customized mathematics lessons in schools and enhance students' engagement through hands-on exploration, it is essential to investigate effective teaching and learning methods that incorporate digital tools and learning materials.

This special sharing groupaims to explore the effectiveness and applicability of AI, technological tools, and learning materials, moving beyond their role as supplementary tools to becoming central instructional resources in mathematics education. Through this initiative, we seek to present and discuss teaching and learning approaches that enable students to intuitively understand mathematical concepts, engage in hands-on problem-solving, and experience personalized learning through artificial intelligence.

Recently, AI-based learning, various mathematical learning tools, and gamification-based lessons have been actively explored. In particular, with the government's AI digital textbook initiative, local education offices are conducting training programs on the use of AI digital textbooks. This workshop will share best-practice cases, discuss the effectiveness of these teaching methods, and derive practical applications for real classroom settings through in-depth discussions.

This special sharing groupwill be conducted as follows (total duration: 90 minutes)

1. Sharing changes in mathematics lessons through digital tools(AI, digital engineering tools ect), play-based and game-based learning(including teachers' instructional goals and students' achievements) (30 min)
2. Group discussion on instructional changes(teaching approaches, content delivery methods, etc.) required for implementing such lessons (30 min)
3. Exchange and discussion of resultsto derive effective teaching and learning strategies (30 min)

Through this special sharing group, participants will gain insights into how AI, technological tools, mathematical learning materials, and game-based learning can enhance student motivation and achievement. By discussing practical applications for real classrooms, we aim to contribute to the realization of engaging, student-centered lessons that foster active participation and creative problem-solving skills.

EXAMPLES OF INDUSTRIAL PROBLEM-SOLVING USING MATHEMATICS

Minjung Gim
National Institute for Mathematical Sciences, Korea, mjgim@nims.re.kr

Seongwon Lee
National Institute for Mathematical Sciences, Korea, slee@nims.re.kr

Semin Oh
Kyungpook National University, Korea, semin@knu.ac.kr

With the rapid advancement of AI technology and its increasing integration into various business models, mathematics and AI are becoming key problem-solving tools in the industrial sector. Amid this trend, mathematicians play a pivotal role by using mathematics and AI to address a wide range of real-world issues in industry.

In this Special Sharing Groups (SSG) session, we will introduce actual industrial problems, demonstrate how they are defined mathematically, and explore the role mathematics played in the problem-solving process. Through these discussions, we hope that mathematics education researchers and teachers will gain a deeper understanding of the value and importance of mathematics in solving industrial problems and come away with fresh perspectives on mathematics education.

This SSG will be conducted in Korean. Three speakers will each give a 30-minute presentation, and the titles and abstracts of their talks are provided below.

1. Minjung Gim

A. Title: Case study of Improving Global Supply Chain Risk Identification Using RCF

B. Abstract: NIMS ICIM addresses industrial and public-sector issues by leveraging mathematics-based AI and data analytics. Recently, uncertainties in global supply chains have been growing due to various major events affecting the global economy—such as pandemics, trade disputes, and geographical factors. In response to these uncertainties, many countries are analyzing supply chain vulnerabilities through diverse methods, proactively identifying and monitoring high-risk items. Korea Association of Machinery Industry (KOAMI), which commissioned this project, selects supply chain risk items based on its own criteria and requested that our institute validate its existing identification method and improve it mathematically. In this presentation, I will introduce the project titled "Improving the Method for Identifying High-Risk Items in Global Supply Chains" and discuss how we redefined and refined the problem from a mathematical perspective. I will cover our approach to measuring import/export trade concentration using entropy, as well as the method I developed for calculating anomaly scores in time-series data by applying a sliding window and transductive inference. Finally, I will show how these techniques were combined to propose an improved method for identifying high-risk items to the client.

2. Seongwon Lee

A. Title: A mathematical methodology for via-point estimation from robot joint motion data

B. Abstract: Collaborative robots (cobots), unlike traditional industrial robots, operate alongside humans in shared workspaces. Analyzing cobot motion and ensuring safety requires estimating the "via-points" of their planned paths from observed motion data. This talk presents algorithms for via-point estimation and discusses the challenges involved. While the implementation details and programming are beyond secondary mathematics curricula, the underlying mathematical concepts—functions and graphs, vectors, and matrices—are fundamental. This presentation aims to illustrate the practical application of these fundamental mathematical concepts in a real-world industrial setting for mathematicians and mathematics educators.

3. Semin Oh

A. Title: Automated Guided Vehicles in Warehouses and Multi-Agent Pathfinding Problems

B. Abstract: In this talk, we introduce Automated Guided Vehicles (AGVs) used in warehouses. We explore how AGVs are utilized in warehouse operations and examine the challenges associated with their deployment. One critical issue in AGV operations is the multi-agent pathfinding (MAPF) problem, where multiple robots must navigate to their destinations without collisions. We provide a mathematical formulation of this problem and discuss various approaches to solving it. Additionally, we highlight applications of MAPF in other industrial sectors.

CHINA-KOREA MATHEMATICS EDUCATION FORUM(PART1): SHAPING THE FUTURE OF MATHEMATICS EDUCATION

Qiaoping Zhang

The Education University of Hong Kong, Hong Kong SAR China, zqiaoping@eduhk.hk

Meiyue Jin

Liaoning Normal University, China, jinmeiyue1968@163.com

Lianghuo Fan

University of Macau, Macau SAR China, lhfan@um.edu.mo

Shuhui Li

East China Normal University, China, shli@math.ecnu.edu.cn

Introduction

In the rapidly evolving world of the 21st century, mathematics education is facing unprecedented challenges and opportunities. The explosive development of information technology, artificial intelligence (AI), and social media is reshaping the way we teach and learn mathematics. To address these changes and strengthen the learning and competitiveness of future students, it is crucial to foster international collaboration and dialogue among mathematics education researchers and practitioners. The *China-Korea Mathematics Education Forum* aims to provide a platform for researchers, educators, and policymakers from China and Korea to reflect on the current state of mathematics education, address its challenges and dilemmas, and explore innovative approaches to teaching and learning in the age of artificial intelligence. By facilitating discussions on critical issues, the forum seeks to map out the future of mathematics education in China, Korea, and around the world.

Purpose and Objectives

The Forum will focus on the following objectives:

- To discuss the current situation and challenges of mathematics education in China and Korea.
- To explore the impact of artificial intelligence and digital technologies on mathematics teaching and learning.
- To exchange research findings and innovative practices in mathematics education.
- To foster collaboration between mathematics educators from the two countries.

Theme

The theme of this Forum is "*Exploring the New Era of Mathematics Education: Challenges and Opportunities in the Age of Artificial Intelligence*". This overarching theme will guide discussions at the forum, with a focus on how mathematics education can adapt to the demands of the future and empower students to thrive in a rapidly changing world.

The forum will include discussions and communications on the following sub-themes:

1. Mathematics Curriculum Design and Assessment Reform
2. Mathematics Teaching and Learning in the Age of AI
3. STEM / STEAM and Mathematics Education
4. Professional Growth of Mathematics Teachers

Participants

- Moderator: Jihwa Noh (Pusan National University)
- Speaker:

Lianghuo Fan (University of Macau)

Chunxia Qi (Beijing Normal University)

Qiaoping Zhang (The Education University of Hong Kong)

Shuhui Li (East China Normal University)

Mangoo Park (Seoul National University of Education)

Woong Lim (Yonsei University)

Soo Jin Lee (Korea National University of Education)

Sheunghyun Yeo (Daegu National University of Education)

Proposed Agenda

Duration: Two days, including Part 1 & Part 2, for a total of 180 minutes.

Participants: Around 100 participants.

- Day 1-Part I (90 mins): 2 Speakers from both China and Korea present insights and innovative approaches related to the forum's theme and sub-themes, followed by a discussion session with the audience.
- Day 2-Part 2 (90 mins): A round-table discussion featuring all speakers from China and Korea, followed by a Q & A session.

Target Audience

The forum is designed for mathematics education researchers, mathematics teachers and educators, curriculum designers and policymakers, as well as graduate students in mathematics education.

Expected Outcomes

The forum aims to achieve the following outcomes:

- A deeper understanding of the current challenges and opportunities in mathematics education in China and Korea.
- Identification of innovative strategies for teaching and learning mathematics in the age of AI.
- Strengthened collaboration and exchange of ideas between mathematics educators from the two countries.
- Establishment of a China-Korea mathematics education research network.
- Publication of forum proceedings or a white paper for global dissemination.

MEMO

MEMO

Special Sharing Groups 2

CROSSING OVER EAST ASIAN MATHEMATICS CURRICULA: A FOCUS ON CURRICULUM REFORM

Chaereen Han, Kyungwon Lee, Tin Lam Toh, Hui-Yu Hsu, Yi-An Chen, Tatsuhiko Seino, Hiroyuki Shimizu, Hyomin Kang, Natsuki Uchikubo, Yoshinori Shimizu, Maitree Inprasitha, Narumon Changsri, Nisakorn Boonsena, Chanika Senawongsa, Jitlada Jaikla

WRITING GOOD ACADEMIC PAPERS FOR EDUCATIONAL STUDIES IN MATHEMATICS

Vilma Mesa, Hui-Yu Hsu

CAN A DECOLONIZED MATHEMATICS SECURE NUMERACY FOR ALL?

Allan Tarp, Yujin Lee

CHINA-KOREA MATHEMATICS EDUCATION FORUM (PART2): SHAPING THE FUTURE OF MATHEMATICS EDUCATION

Qiaoping Zhang, Meiyue Jin, Lianghuo Fan, Shuhui Li

KOREA 2025

EARCOME9

The 9th ICMI-East Asia Regional Conference on Mathematics Education

CROSSING OVER EAST ASIAN MATHEMATICS CURRICULA: A FOCUS ON CURRICULUM REFORM

Chaereen Han
Jeonju National University of Education, Korea, chaereen@jnue.kr

Kyungwon Lee
Seoul National University, Korea, kyungwon.lee.snu@gmail.com

Tin Lam Toh
Nanyang Technological University, Singapore, tinlam.toh@nie.edu.sg

Hui-Yu Hsu
National Tsing Hua University, Taiwan, huiyuhsu@mx.nthu.edu.tw

Yi-An Chen
National Tsing Hua University, Taiwan, ebonest0110@gmail.com

Tatsuhiko Seino
Tokyo Gakugei University, Japan, tseino@u-gakugei.ac.jp

Hiroyuki Shimizu
University of Yamanashi, Japan, hiroyuki@yamanashi.ac.jp

Hyomin Kang
University of Tsukuba, Japan, s2030317@u.tsukuba.ac.jp

Natsuki Uchikubo
University of Tsukuba, Japan, s2430306@u.tsukuba.ac.jp

Yoshinori Shimizu
University of Tsukuba, Japan, yshimizu@human.tsukuba.ac.jp

Maitree Inprasitha
Khon Kaen University, Thailand, imaitr@kku.ac.th

Narumon Changsri
Khon Kaen University, Thailand, changsri_crme@kku.ac.th

Nisakorn Boonsena
Khon Kaen University, Thailand, nisabo@kku.ac.th

Chanika Senawongsa
Khon Kaen University, Thailand, chansen@kku.ac.th

Jitlada Jaikla
Khon Kaen University, Thailand, jitlja@kku.ac.th

Mathematics curricula are constantly evolving. While the nature of these changes varies across countries, the central focus remains on preparing students for the future. This SSG examines the latest mathematics curriculum reforms in five East Asian countries—Singapore, Tiwan, Japan, Thailand, and Korea—which have long been recognized for their high levels of mathematical achievement and high-quality classroom practices (Silver, 2009)—analyzing their directions and implications.

Our focus extends beyond a simple comparison of curriculum content. As Li and Shimizu (2009) state, “As a cultural activity, mathematics education is situated in a specific cultural setting and also evolves in ways that are valued in that culture.” By examining each other’s curricula, we aim to gain an external perspective on our own educational cultures and identify shared values underlying mathematics education in East Asia.

To facilitate this discussion, we have invited leading researchers from these five countries, and the session is structured, with each country’s presentation allocated 15 minutes.

Tin Lam TOH (Singapore) will present the recent cycles of revision in the Singapore mathematics curriculum. His talk will focus on revisions to pedagogical principles, particularly: (1) The emphasis on learning experiences in mathematics teaching and learning. (2) Teaching through or toward *big ideas* in mathematics. He will explore how these principles are translated from the planned curriculum (mathematics syllabus documents) to the intended curriculum (Singaporean mathematics textbooks), using perspectives from both mathematics and mathematics education.

Hui-Yu Hsu and Yi-An Chen (Taiwan) will provide a comprehensive account of how geometric calculation problems have evolved in the Taiwanese mathematics curriculum and textbooks over the past two decades. Specifically, they will examine how these problems serve as key instructional materials designed to bridge students’ understanding from computational geometry to formal geometric proofs. Their analysis contributes to ongoing discussions on effective curriculum design and instructional strategies, both within Taiwan and in broader international contexts that aim to foster strong geometric reasoning skills among secondary school students.

Tatsuhiko Seino, Hiroyuki Shimizu, Hyomin Kang, Natsuki Uchikubo, and Yoshinori Shimizu (Japan) will introduce the key focus areas of the revised Japanese mathematics curriculum. A major emphasis of the reform is ensuring continuity in learning between elementary and junior high school, facilitating a seamless transition in students’ mathematical development. The speakers will highlight the importance of mathematical perspectives and ways of thinking as well as mathematical activities in deepening students’ understanding.

Maitree Inprasitha, Narumon Changsri, Nisakorn Boonsena, Chanika Senawongsa, and Jitlada Jaikla (Thailand) will share their experience in developing Thailand’s competency-based national curriculum, which is planned for implementation in 2026. Thailand’s national curriculum and textbooks focus primarily on knowledge with less emphasis on practical or professional competency. The adoption and implementation of a paradigm shift from a product-oriented approach to a product-process-oriented approach in curriculum reform has not been universal in the broader educational community in Thailand. Since 2006, they have been implementing translated Japanese textbooks featuring problem-solving approaches as part of their effort to develop a more competency-based curriculum.

Kyungwon Lee (Korea) will present on the 2022 revised mathematics curriculum of Korea. The Korean mathematics curriculum has been restructured to address societal changes, including digital transformation (such as AI), climate change, and declining student populations. The reform aims to equip students with the necessary competencies for the future by reorganizing content for deeper learning, incorporating various national and social demands, and establishing a diverse selection of elective courses that promote student autonomy. He will particularly focus on how the curriculum responds to changes in mathematics education environments and teaching methods, considering the growing necessity for remote education and advancements in AI technology.

Through these discussions, we hope participants gain valuable insights into the evolving landscape of mathematics education in East Asia, fostering a deeper understanding of the cultural and pedagogical values that shape our curricula.

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WRITING GOOD ACADEMIC PAPERS FOR EDUCATIONAL STUDIES IN MATHEMATICS

Vilma Mesa
University of Michigan, United States, vmesa@umich.edu

Hui-Yu Hsu
National Tsing Hua University, Taiwan, huiyuhsu@mx.nthu.edu.tw

In this session, we share information relevant to authors interested in writing papers that will be reviewed positively in Educational Studies in Mathematics (ESM). In this interactive session, the participants will learn about the journal, the publishing processes, and common weaknesses that result in negative appraisals from the reviewers. Participants will be encouraged to discuss strategies to handle reviews and revisions, and to learn about what constitutes a helpful review. This interactive session will be offered in the Special Sharing Group.

Keywords: Educational Studies in Mathematics; Writing Skills; High Quality Journal Paper; Response to the Editor

For most academics, the process of writing for journals can be daunting, especially when they have heard stories of, or experienced, negative, non-constructive feedback from reviewers, or when the decisions made by editors have not been positive. However, writing for journal publication can be seen as engaging in a conversation with colleagues about mathematics education research and about the knowledge that we produce; with this perspective, even negative recommendations for publication can be springboards for better papers. Usually, when manuscripts are not reviewed positively it is because the engagement with the community that reads the journal or the connection to pressing issues in the field is weak.

Mathematics education has multiple journals for publication. These journals vary in terms of audience, scope, publishing systems, editorial practices, and standards. All these result in different expectations about genre and other processes that can be difficult to navigate, especially for international journals. As one of the most important international journals in mathematics education, *Educational Studies in Mathematics* (ESM) publishes a wide range of manuscripts on a wide range of topics, but it has strict length policies and a special system for managing the review and publication of manuscripts.

In this session, Drs. Hui-Yu Hsu (Editorial Board Member) and Vilma Mesa (co Editor-in-Chief) will lead a discussion with the attendees based on their experiences working with ESM. By combining expert insights and hands-on activities, the session aims to equip participants with the tools and strategies needed to receive positive feedback from ESM handling editors and reviews.

This 90-minute section will be organized as follows:

1. Information about the journal and its processes (10 minutes), describing ESM's history, organization, and publication standards.

2. Main reasons that can result in a rejection of a paper (15 minutes) such as structuring and justifying the work, attending to coherence between various components of the presentation, and connections to current work in the field.
3. Strategies to address weak aspects in manuscripts (20 min), via an examination of excerpts from published articles that illustrate ways in which rationale, theoretical framing, methodology, and claims are handled.
4. Handling the editor's and the reviewers' comments (15 min), via an examination of sample reviews for the same paper and appropriate ways to address the comments. and
5. Engaging in the process of identifying a helpful review (20 mins, Mesa et al., 2021), via an examination of the criteria proposed by ESM's associate editors.

The session will be rounded up with 10 minutes dedicated to questions and answers, done collaboratively over an online document. The session will be interactive and guided by the participants' questions.

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CAN A DECOLONIZED MATHEMATICS SECURE NUMERACY FOR ALL?

Allan Tarp
MATHeCADEMY.net, Denmark, Allan.Tarp@gmail.com

Yujin Lee
Kangwon National University, YLEE@kangwon.ac.kr

This Special Sharing Group will discuss 'Quality Education', the fourth of the 17 UN Sustainable Development Goals, which has as a goal target to "By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy". Looking at the relationship between numeracy and mathematics, a core question is: Which to teach and learn first?

Introduction

"That is not four. That is two twos." Said a 3year-old when asked "How many years next time?" and seeing 4 fingers 2 by 2. Which indicates that children have their own number-language before they are asked to shift to the school's version. The child sees what exists, bundles of twos in space serving as units when counted in time. And as in the word-language, the child's number-language also uses a full sentence with an outside existing subject, a linking verb, and an inside predicate.

The school thus could help children to further develop their own number-language that uses two-dimensional bundle-numbers with units where multiplication always holds by simply changing the unit, e.g., from 4s to tens where 3 x 4 = 12 states that 3 4s may be recounted in tens as 1.2 tens.

So, by what right and how ethical is it when the school imposes upon the children its own one-dimensional non-unit numbers where addition without units only holds inside the school but seldom outside the school where '2+1 = 3' typically is falsified, e.g., by 2 days + 1 week = 9 days?

To separate reliable 'multiplication-math' from unreliable 'addition-math' the latter should maybe be called 'mathematism' (Tarp, 2018), true inside but seldom outside school. But then, why teach addition of non-unit numbers inside schools when outside students need to add numbers with units?

We therefore could ask: To impose unreliable addition of one-dimensional non-unit numbers upon students that use multiplication in their two-dimensional unit numbers, isn't that an example of "a colonization of the life world by the system", the key concept in the sociology of Jürgen Habermas?

Then we could ask if sociological imagination should use demodeling to bring inside concepts back once more to their outside roots to decolonize mathematics and its education so it may meet the fourth of the 17 UN Sustainable Development Goals that has as a goal target to "By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy".

Decolonization will not be easy as seen by different definitions of 'numerate'. The English Oxford Dictionary defines it as being "competent in the basic principles of mathematics, esp. arithmetic". In contrast, the American Merriam-Webster dictionary defines it as "having the ability to understand and work with numbers." In their common history, England once colonized America. So, the difference may hide a hidden agenda where existence is colonized by a chosen essence instead of preceding it. The English uses the passive term ‘competent’ where the American uses the active term ‘work’. The word ‘competent’ is a predicate, a non-action word, I cannot ‘competent’ something, I can only be judged as competent by someone who is competent. In contrast, ‘work’ is an action word, a verb, since with my body and mind I can work on something and test the result to see if it works.

Also, there is a difference between the words ‘mathematics’ and ‘numbers.’ Again, mathematics is a non-action word, I cannot ‘mathematics’ or even ‘math’ a thing. In contrast, ‘number’ is both a verb and a noun since I can number different degrees of Many to produce a number for later calculations.

One example of a decolonized mathematics education that respects the children’s bundle-numbers with units may be found in the article “Mastering Many by counting, re-counting and double-counting before adding on-top and next-to.” The article shows that a ‘counting before adding’ approach leads to the same concepts as a traditional approach but with different identities, and in a different order. Counting in 3s leads to 9 as a bundle-bundle, a B^2, which leads on to squares, square roots, and quadratics. Counting transforms the operations into icons where division and multiplication become a broom and a lift that pushes-away bundles to be stacked as shown when recounting 8 in 2s as 8 = (8/2) x 2, or with T and B for Total and Bundle, T = (T/B) x B, that creates per-numbers when recounting in physical units, $ = ($/kg) x kg. Subtraction becomes a rope that pulls-away the stack to find the unbundled that, placed on-top of the stack as part of an extra bundle, become decimals, fractions, or negatives, e.g., 9 = 4B1 = 4½ = 5B-1 2s. Finally, addition becomes a cross showing the two ways to add stacks, on-top using the linearity of recounting to make the units like, or next-to creating integral calculus by adding areas, which is also used when adding per-numbers needed to be multiplied to areas before adding. All this provides an ‘Algebra Square’ showing how to unite the four types of existing numbers: multiplication and addition unite like and unlike unit-numbers, and power and integration unite like and unlike per-numbers. And how to split totals with the opposite operations: division and subtraction, together with root or logarithm and differentiation.

Calculations unite/*split Totals in*	Unlike	Like
Unit-numbers m, s, kg, $	$T = a + n$ $T - n = a$	$T = a * n$ $T/n = a$
Per-numbers m/s, $/100$ = %	$T = \int f\,dx$ $dT/dx = f$	$T = a$^b $\sqrt[b]{T} = a$ $loga(T) = b$

Figure 1. The Algebra Square shows the ways to reunite unlike and like unit- and per-numbers

Reuniting like and unlike unit- and per-numbers is “ability to understand and work with numbers” to produce quantitative tales, reports, and literature; and to discuss to which genre they belong, fact or fiction or fake. Which will allow a communicative turn in the number-language as the one that took place in foreign language education in the 1970s allowing all to use the English language without first knowing its abstract grammar. Which again may create a world where numeracy is no longer a privilege for an elite that colonize the number-language with unreliable mathematism.

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CHINA-KOREA MATHEMATICS EDUCATION FORUM(PART2): SHAPING THE FUTURE OF MATHEMATICS EDUCATION

Qiaoping Zhang

The Education University of Hong Kong, Hong Kong SAR China, zqiaoping@eduhk.hk

Meiyue Jin

Liaoning Normal University, China, jinmeiyue1968@163.com

Lianghuo Fan

University of Macau, Macau SAR China, lhfan@um.edu.mo

Shuhui Li

East China Normal University, China, shli@math.ecnu.edu.cn

Introduction

In the rapidly evolving world of the 21st century, mathematics education is facing unprecedented challenges and opportunities. The explosive development of information technology, artificial intelligence (AI), and social media is reshaping the way we teach and learn mathematics. To address these changes and strengthen the learning and competitiveness of future students, it is crucial to foster international collaboration and dialogue among mathematics education researchers and practitioners. The *China-Korea Mathematics Education Forum* aims to provide a platform for researchers, educators, and policymakers from China and Korea to reflect on the current state of mathematics education, address its challenges and dilemmas, and explore innovative approaches to teaching and learning in the age of artificial intelligence. By facilitating discussions on critical issues, the forum seeks to map out the future of mathematics education in China, Korea, and around the world.

Purpose and Objectives

The Forum will focus on the following objectives:

- To discuss the current situation and challenges of mathematics education in China and Korea.
- To explore the impact of artificial intelligence and digital technologies on mathematics teaching and learning.
- To exchange research findings and innovative practices in mathematics education.
- To foster collaboration between mathematics educators from the two countries.

Theme

The theme of this Forum is "*Exploring the New Era of Mathematics Education: Challenges and Opportunities in the Age of Artificial Intelligence*". This overarching theme will guide discussions at the forum, with a focus on how mathematics education can adapt to the demands of the future and empower students to thrive in a rapidly changing world.

The forum will include discussions and communications on the following sub-themes:

1. Mathematics Curriculum Design and Assessment Reform
2. Mathematics Teaching and Learning in the Age of AI
3. STEM / STEAM and Mathematics Education
4. Professional Growth of Mathematics Teachers

Participants

- Moderator: Jihwa Noh (Pusan National University)
- Speaker:

Lianghuo Fan (University of Macau)
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Mangoo Park (Seoul National University of Education)
Woong Lim (Yonsei University)
Soo Jin Lee (Korea National University of Education)
Sheunghyun Yeo (Daegu National University of Education)

Proposed Agenda

Duration: Two days, including Part 1 & Part 2, for a total of 180 minutes.

Participants: Around 100 participants.

- Day 1-Part I (90 mins): 2 Speakers from both China and Korea present insights and innovative approaches related to the forum's theme and sub-themes, followed by a discussion session with the audience.
- Day 2-Part 2 (90 mins): A round-table discussion featuring all speakers from China and Korea, followed by a Q&A session.

Target Audience

The forum is designed for mathematics education researchers, mathematics teachers and educators, curriculum designers and policymakers, as well as graduate students in mathematics education.

Expected Outcomes

The forum aims to achieve the following outcomes:

- A deeper understanding of the current challenges and opportunities in mathematics education in China and Korea.
- Identification of innovative strategies for teaching and learning mathematics in the age of AI.
- Strengthened collaboration and exchange of ideas between mathematics educators from the two countries.
- Establishment of a China-Korea mathematics education research network.
- Publication of forum proceedings or a white paper for global dissemination.

MEMO

Special Sharing Groups 3

KOREA 2025

EARCOME9

The 9th ICMI-East Asia Regional Conference on Mathematics Education

HIGH-QUALITY MATHEMATICS INSTRUCTION: WHAT DO WE MEAN?

Ban Heng CHOY

National Institute of Education, Nanyang Technological University, Singapore, banheng.choy@nie.edu.sg

Introduction

The world has become more polarized. And it is also the case with mathematics education. In recent years, there has been a polarizing discourse, fueled by recent iterations of the 'math war' (Chernoff, 2019; Yoon et al., 2021), on what constitutes high-quality mathematics instruction. In Australia, for example, there has been a push towards the use of explicit teaching, which was supposedly based on principles derived from the science of learning, and a push-back from many mathematics educators about the use of a single main approach to teaching (Brown, 2024; Sawatzki & Armour, 2025). Similarly, in New Zealand, the government has implemented a refreshed mathematics curriculum, focusing on "structured numeracy"—something supposedly based on "Singapore mathematics" (Murray, 2024). In all these polarizing conversations about high-quality mathematics instruction, the language used promoted a particular form of pedagogical approach, even though it is widely recognized that effective teaching can take different forms (Choy & Dindyal, 2024; Kilpatrick et al., 2001). Although mathematics education researchers generally proposed the use of different instructional and pedagogical approaches, the balance required remains an open question. What is more pressing, perhaps, is the lack of clarity about the essential features of high-quality mathematics instruction, and how it might look like in different parts of the world.

What do we mean by high-quality mathematics instruction?

High-quality mathematics instruction is often characterized by the structure of the lessons, the tasks used, the kinds of classroom discourses, and how content is presented. However, much of the narrative on high-quality mathematics instruction has been shaped by the West. For example, mathematically productive whole-class discussions are premised on the use of rich tasks, often centered around one task for the whole lesson (Bobis et al., 2021; Ingram et al., 2019; Smith & Stein, 2011; Sullivan et al., 2013). Although similar approaches can be seen in some East-Asian classrooms (Ng et al., 2020; Takahashi, 2021), high-quality instruction can also take place with the use of typical problems—standard textbook or examination-type questions—which is more common in East-Asian classrooms, such as those in China and Singapore (Choy & Dindyal, 2021; Wong et al., 2013). What is clear from these images of high-quality mathematics instruction is the complexity and multiple layers of meanings embedded in these seemingly direct instructional approaches. It is not a matter of traditional versus reform-based teaching approaches, nor simply a distinction between the standard *Initiate-Response-Evaluate* (IRE) discourse patterns and the more discursive ones. Instead, it is crucial for us to understand why and how these seemingly "traditional" approaches work so that practitioners can use these different approaches in ways that focus on the substance, and not the forms, of high-quality instruction. Hence, it is important for the mathematics education community to understand and characterize high-quality instruction so that we can better enhance our instruction in the age of AI and digital transformation.

Aims of this Special Sharing Group (SSG)

In light of the preceding discussion, this SSG aims to promote sharing and collaboration between mathematics educators, researchers, and practitioners who have a common shared interest in *understanding* and *characterizing* high-quality mathematics instruction across different contexts and cultures. More specifically, we want to highlight distinctives of high-quality mathematics instruction from the East-Asian perspective, in addition to perspectives from other parts of the world. For the purpose of facilitating discussions, participants of this SSG are expected to prepare a description of an instance of what they perceived as high-quality mathematics instruction for sharing during the session. The idea is not to evaluate the different snapshots of high-quality mathematics instruction, but to develop a common understanding of distinctive features that characterizes such instruction. The SSG will follow the outline delineated below:

1. An overview of the issue of characterizing high-quality mathematics instruction
2. A snapshot of high-quality “explicit instruction” in Singapore
3. Sharing by other participants
4. Discussion on future collaborations (possibly a Special Issue in one of the journals)

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MATHEMATICAL ARGUMENTATION FOR SUSTAINABILITY: EXPLORING THE CLAIM-EVIDENCE-REASONING (CER) FRAMEWORK IN SOCIO-SCIENTIFIC INQUIRY

Suparat Chuechote
Faculty of Education, Naresuan University, Thailand, chuechote@gmail.com

Natcha Kamol
Faculty of Education, Chiang Mai University, Thailand, natcha.ka@cmu.ac.th

Artorn Nokkaew
Faculty of Education, Naresuan University, Thailand, art.nokkaew@gmail.com

Introduction

The Anthropocene, characterized by unprecedented human-induced environmental change, necessitates a transformative shift in education—particularly mathematics education—to cultivate critical thinking, systems reasoning, and decision-making skills essential for addressing global challenges (OECD, 2023). The PISA 2025 Science Framework emphasizes the importance of equipping students to engage with scientific discourse, sustainability concerns, and data interpretation. However, traditional mathematics instruction often remains disconnected from real-world socio-scientific issues (OECD, 2023; Evagorou & Nicolaou, 2020). Integrating the Claim-Evidence-Reasoning (CER) framework offers a structured approach to bridging mathematical concepts with pressing environmental and social challenges. By guiding students to formulate claims, support them with evidence, and justify them through reasoning, CER fosters interdisciplinary learning and prepares students for data-informed decision-making (Fielding-Wells, 2016).

This study investigates how pre-service mathematics teachers from two major universities in Thailand design CER-based lesson plans that incorporate socio-scientific inquiry on topics such as urbanization and PM2.5 pollution, thereby contributing to a more relevant pedagogical strategies that support teacher preparation programs and professional development efforts in fostering data-driven reasoning, sustainability-focused inquiry, and real-world mathematical thinking.

Theoretical Framework

The Claim-Evidence-Reasoning (CER) Framework in Mathematics

The Claim-Evidence-Reasoning (CER) framework comprises three essential components: claim, where students formulate a hypothesis or statement addressing a problem; evidence, which draws on empirical data, mathematical models, and research findings to support the claim; and reasoning, which connects the evidence to the claim by applying mathematical principles and real-world contexts (Fielding-Wells, 2016). Integrating CER into mathematical tasks promotes quantitative literacy, analytical reasoning, and real-world application skills, enabling students to develop evidence-based argumentation through well-designed tasks combined with effective classroom instruction (Moothummachai & Kamol, 2020).

The Role of Mathematics in the Anthropocene and PISA 2025 Competencies

The OECD's PISA 2025 Science Framework emphasizes the need for students to develop competencies that (OECD, 2023):

- Explain phenomena scientifically, using mathematical models to analyze global issues.
- Construct and evaluate designs for inquiry, applying data interpretation and systems thinking to sustainability challenges.
- Research, evaluate, and use scientific information for decision-making, incorporating quantitative reasoning into socio-political discourse.

To effectively align mathematics education with PISA 2025 competencies, pre-service teacher training must ensure that lesson planning fosters critical inquiry, interdisciplinary learning, and the application of mathematical reasoning in real-world contexts.

Pre-Service Mathematics Teacher Education and Socio-Scientific Inquiry

Mathematics educators increasingly recognize the need for context-based learning, where mathematical concepts are applied to real-world socio-environmental issues (Morsanyi, Prado, & Richland, 2018). Pre-service teacher education plays a pivotal role in equipping future educators with strategies for integrating mathematics with contemporary challenges. Participatory research in teacher education emphasizes collaborative curriculum design and lesson co-development, enabling pre-service teachers to construct lesson plans that incorporate quantitative analysis, sustainability concepts, and policy evaluation (Nokkaew & Chuechote, 2022). This study investigates how pre-service teachers conceptualize and implement CER-based mathematical inquiry, focusing on local current issues, such as urbanization, PM2.5 pollution, diet marketing analysis as socio-scientific case studies.

Research Design

This study employs a participatory research design, engaging 93 pre-service mathematics teachers in collaborative lesson planning to examine how they structure CER-based mathematical investigations and integrate PISA 2025 competencies. Lesson plans were analyzed based on their mathematical content integration (statistics, geometry, algebra in socio-scientific modeling), CER application (claim structure, evidence selection, reasoning quality), and alignment with PISA competencies (scientific explanation, inquiry, and data literacy).

Results and Discussion

Pre-service teacher lesson plans exhibited varying levels of CER integration and alignment with PISA 2025 competencies. The table below summarizes key findings.

Table 1. Analysis of Pre-Service Teacher Lesson Plans

Lesson Theme	Mathematical Content Integration	Types of Evidence and Reasoning	Alignment with PISA 2025 Competencies
PM2.5 Pollution Analysis	Statistics, Algebra (Trend analysis, AQI calculations)	Air pollution datasets, regression modeling to assess pollution impact	Scientific explanation of air quality trends, inquiry into policy solutions, and evaluation of mitigation strategies
Urbanization and Population Density	Geometry, Spatial Mathematics (Urban planning models)	Census data, land use maps, urban infrastructure evaluation	Systems thinking in urban planning, evaluation of sustainability, data-driven decision-making
Food Packaging and Nutritional Claims	Ratio, Percentage, Proportions (Nutritional comparison)	Product labels, statistical comparisons, consumer deception analysis	Critical evaluation of consumer data, statistical literacy, and evidence-based decision-making

Discussion on Awareness of PISA 2025 Competencies with CER Application

Pre-service teachers increasingly grounded their mathematical arguments in tangible data—such as air pollution indices, demographic maps, and product nutritional information—demonstrating a shift from procedural mathematics to data-driven problem solving essential for the Anthropocene era (OECD, 2023). However, while they effectively used empirical evidence, many struggled to articulate complex reasoning chains linking mathematical models to broader societal impacts like public health or urban sustainability, highlighting the need for deeper training in systems reasoning and advocacy-based inquiry (Fielding-Wells, 2016; Evagorou & Nicolaou, 2020).

Discussion on Pedagogical Directions for Professional Development

To meaningfully implement the CER framework in mathematics classrooms, professional development must prioritize a shift in pedagogical practice, embedding reasoning, inquiry, and sustainability as central pillars of instruction. This transformation moves beyond simply teaching mathematical procedures toward cultivating students' critical engagement with real-world issues.

One powerful direction is through inquiry-based socio-mathematical tasks. Rather than beginning with predefined problems, teachers are encouraged to design activities that emerge from authentic societal dilemmas. Students should be prompted to pose their own questions, collect relevant data, and apply mathematical reasoning to construct and critique claims. In doing so, they learn that inquiry is iterative, requiring constant refinement and re-evaluation—a process central to both scientific thinking and mathematical problem solving (Giri & Paily, 2020; Register, Stephan, & Pugalee, 2021).

A second necessary shift involves integrating argumentation explicitly within lesson design (McNeill & Berland, 2010). Lessons must scaffold CER structures intentionally by embedding question prompts, supplying curated data sets, and encouraging collaborative discussions. Through these frameworks, students can analyze complex situations such as conflicting urban planning models or environmental trends, using mathematics not just as a calculating tool but as a medium for evidence-based discourse.

Central to this transformation is the scaffolding of reasoning practices. Teachers must progressively model how data links with mathematical principles and contextual understanding. Techniques such as evidence mapping and reasoning chains provide visual supports that help students structure their arguments coherently and move beyond surface-level conclusions (Giri & Paily, 2020). As students practice these habits of mind, they become more adept at constructing sophisticated, data-driven arguments applicable across disciplines (Fielding-Wells, 2024).

Importantly, CER pedagogy must also foreground ethical reasoning through mathematical modeling. Students should be guided not only to assess the technical validity of models but to interrogate who benefits, who is disadvantaged, and what assumptions underlie the calculations. This justice-oriented perspective positions mathematics as a tool for social critique and transformation, essential in an era marked by increasing social and environmental challenges (Register, Stephan, & Pugalee, 2021).

Conclusion

This study highlights the transformative potential of integrating the CER framework into mathematics education to address the competencies emphasized in the PISA 2025 framework. Through participatory lesson design, pre-service teachers demonstrated an emerging ability to ground mathematical inquiry in real-world socio-scientific issues, though challenges in articulating complex reasoning and systemic impacts remain. Embedding inquiry-based socio-mathematical tasks, explicit argumentation structures, and scaffolded reasoning practices can foster deeper critical engagement. Furthermore, positioning mathematics as a tool for ethical reasoning and social critique enables students to apply mathematical thinking to sustainability and justice-oriented challenges.

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GLOBAL INSIGHTS AND PERSPECTIVES: EXPANDING THE REACH OF MATHEMATICS EDUCATION JOURNALS IN KOREA

Kyong Mi Choi
University of Virginia, USA, kc9dx@virginia.edu

Na Young Kwon
Inha University, Korea, rykwon@inha.ac.kr

Soo Jin Lee
Korea National University of Education, Korea, sjlee@knue.ac.kr

Mimi Park
Gyeongin National University of Education, Korea, mpark@ginue.ac.kr

Sheunghyun Yeo
Daegu National University of Education, Korea, shyeo@dnue.ac.kr

Mathematics education research plays a vital role in shaping effective teaching methodologies, curriculum development, and policy decisions worldwide (Inglis & Foster, 2018; Schoenfeld, 2016). South Korea has developed a well-established tradition in mathematics education research, producing both high-quality academic and practice-based studies (Pang, 2020). However, despite this strong research foundation, mathematics education journals in Korea have yet to gain sufficient visibility in international academic discussions. This proposal aims to address this gap by promoting mathematics education journals in Korea to a global audience, encouraging international researchers to contribute their work, and facilitating knowledge exchange.

This session will be led by a group of the chief editors of four major mathematics education journals in Korea. These journals include *The Mathematical Education* and *Mathematics Education Research and Practice,* which are published by the Korean Society of Mathematical Education, as well as *The Journal of Educational Research in Mathematics* and *School Mathematics*, which are published by the Korean Society of Educational Studies in Mathematics. By enhancing the accessibility, visibility, and engagement of these journals on an international scale, this session will foster academic collaboration and advance mathematics education research globally. To ensure meaningful discussions on these issues, the session will include a structured panel discussion that brings together international mathematics education researchers. The panel discussion will focus on topics such as the challenges and opportunities of publishing in those four journals, strategies for increasing international engagement, and the future direction of mathematics education research. Following the panel discussion, a live Q&A session will be conducted to encourage direct engagement between the audience and the panelists. Participants will have the opportunity to ask questions about the submission and review process, potential research topics of interest, and ways to collaborate with Korean mathematics education researchers. This interactive session will provide valuable insights and address concerns that international scholars may have about contributing to mathematics education journals in Korea.

Through this session, we anticipate several key outcomes. The session will strengthen collaboration between Korean and global mathematics education scholars, fostering a more interconnected research community. Additionally, the exchange of diverse perspectives will contribute to the advancement of mathematics education research and its practical applications in classrooms worldwide. Promoting mathematics education journals in Korea to an international audience is a crucial step toward integrating Korean research into the global academic community. We invite international mathematics educators to join the session and collaborate in enriching the dialogue on key issues in mathematics education.

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OUTDOOR MATH MODELING – A UNIQUE CLASSROOM ACTIVITY WITH MATHCITYMAP

Joerg Zender
University of Cologne, Germany, joerg.zender@uni-koeln.de

Matthias Ludwig
University of Frankfurt, Germany, ludwig@math.uni-frankfurt.de

Proposal for Special Sharing Groups

Mathematical modeling tasks in schoolbooks are often perceived as monotonous and lack real-world relevance, making it difficult to engage students in meaningful problem-solving activities (Vos, 2013). In response to this challenge, the MathCityMap Project (MCM-Project) aims to inspire students by integrating mathematical modeling into real-world contexts. Through this approach, we strive to provide a more dynamic and interactive learning experience that fosters mathematical thinking beyond the traditional classroom setting.

The foundation of the MCM-Project lies in the concept of math trails, an idea first introduced to the broader public in Melbourne, Australia, in 1984 (Blane & Clarke, 1984). A math trail is essentially a guided walk during which participants encounter and solve mathematical problems embedded in their surroundings. This method encourages students not only to discuss and solve problems but also to create their own mathematical tasks based on their observations (Shoaf et al., 2004). Solving these tasks requires direct interaction with the environment or specific objects, reinforcing the importance of mathematical modeling. By transforming real-world situations into mathematical representations, students develop critical problem-solving skills and a deeper understanding of applied mathematics. Furthermore, research has shown that math trails significantly enhance student motivation and learning success, as they provide a hands-on, engaging experience that connects mathematical concepts to everyday life (Zender et al., 2020).

With the advancement of modern technology, the math trail concept has experienced a revival, leveraging digital tools to enhance engagement and accessibility (Ludwig et al., 2013). The MCM-Project utilizes a dedicated MCM app for mobile devices, which provides users with trail guides, problem-solving hints, and instant feedback on their answers. In addition, the MCM web portal enables educators and learners to access, explore, and modify a vast collection of math trail tasks. This platform fosters collaboration by allowing registered users to customize tasks to fit their specific needs. While task-sharing is optional, users can exchange problems within a selected group of friends or colleagues, promoting a collaborative approach to mathematical exploration.

During this interactive workshop, participants will gain insights into the MCM-Project and its underlying theoretical framework. We will demonstrate how math trails can be created and implemented effectively in educational contexts. As part of the session, we will design and execute a math trail within the conference venue, allowing attendees to experience firsthand the benefits of this method. Participants will have access to measuring tools and mobile devices, ensuring an inclusive hands-on experience for all. Following the trail walk, attendees will engage in a collaborative task-creation session, applying what they have learned in a learning-by-doing manner. By the end of the workshop, each participant will have a comprehensive understanding of math trails and will be equipped with the necessary skills to design their own trails using the MCM system.

To fully engage in the workshop, we encourage participants to download the MathCityMap app from the Google Play Store or Apple App Store (free of charge). More information about the project and its resources can be found at www.mathcitymap.eu.

This workshop builds on our previous successful implementations at ICMI-13 in Hamburg, ICTMA-18 in Cape Town, EARCOME8 in Taipeh (Ludwig et al., 2018) and many more internal workshops for schools, where educators and researchers enthusiastically embraced the potential of math trails for mathematics education.

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PP1-01

FROM TEACHER NOTICING TO VALUES ALIGNMENT PROCESS: A SYSTEMATIC REVIEW

Haomin Fang
The University of Melbourne, Faculty of Education, Australia, haominf@student.unimelb.edu.au

Keywords: teacher noticing, values, mathematical well-being

Introduction

Values are aligned by different stakeholders in a mathematics classroom to ensure effective activities and interactions. As a pivotal aspect of values alignment research, students' mathematical wellbeing (MWB) can be enhanced when teachers align their personal or instructional values with those of the students (Hill et al., 2022). Hill et al. (2022) conceptualized a MWB model encompassing seven ultimate values for students: accomplishment, cognitions, engagement, meaning, perseverance, positive emotion, and relationships. Teachers, acting as facilitators in mathematics classrooms, have competencies that play a crucial role in aligning the values of all parties. Teacher noticing (TN) is regarded as a vital competency in mathematics teaching, encompassing the ability of teachers to identify key elements in the teaching situation and establish connections between specific events and broader teaching principles through interpretation (van Es & Sherin, 2002). Jacobs et al. (2010) elucidated the TN theoretical framework, and identified a TN trajectory that comprises three key behaviors: attending, interpreting, and responding. Despite its importance, research on TN in relation to values alignment remains limited, and the interplay between the TN behavior trajectory and the values alignment process is yet to be fully explored. Consequently, this study poses the following research question: *From the perspective of mathematical well-being, how does mathematics teacher noticing influence the process of values alignment in a mathematics classroom?*

Methodology

The systematic review search strategy was employed to collect data. Initially, EBSCO was selected as the search platform, and four databases pertinent to the field of education were chosen. Keywords were constructed using Boolean search mode, aligned with the research question and theoretical frameworks. The final search strings was: (math* and ("teacher noticing")) AND (wellbeing or well-being or "well being" or accomplishment or cognition* or engagement or meaning or perseverance or positive emotions or relationships) AND ((primary or elementary or middle or secondary or high) and (school* or education)) NOT TI(review). After configuring search parameters and applying exclusion criteria, fifteen articles were yielded. Subsequently, thematic review served as the data analysis method, which was conducted with both deductive and inductive coding. The coding was based on students' ultimate values in the MWB model and TN trajectory, encompassing open coding, axial coding, and selective coding throughout the process.

Results and Discussion

Following the coding of retrieved articles, the results were categorized into three themes and seven sub-themes. Theme 1, *Attending*, pertains to participants' attention to classroom situations and encompasses ten articles. It includes three sub-themes, which are learning strategies, study achievement, and classroom performance. The situations participants attended can correspond with students' ultimate values of accomplishment, cognitions, engagement, meaning, and relationships. Theme 2, *Interpreting*, involves ten articles and relates to participants' understanding of the classroom situations they attended. Two sub-themes within Theme 2 are "with the current situation" and "with the previous experience". Notably, participants who interpreted classroom situations by integrating their prior experience were all in-service teachers. Theme 3, *Responding,* includes nine articles and refers to participants' verbal or behavioral reactions based on their interpretation, which are categorized into two sub-themes. Participants' responding behaviors correspond with students' ultimate values of accomplishment, cognitions, positive emotions, perseverance, relationships. Response behavior can be verbal and behavioral, as well as positive and relatively negative.

The role of TN in the process of values alignment is primarily evident in teaching scenarios in where teachers respond based on their attention. Typically, when teachers attend to a classroom situation that corresponds to a particular value, their response is often characterized by the same value. However, evidence indicates that responses to a situation related to one value can sometimes manifest through behaviors aligned with other values. No participants interpret the classroom situation through the lens of students' MWB, possibly due to the relatively recent emergence of the MWB concept, leading to a lack of conscious connection to values or MWB among mathematics teachers. A more significant reason of this finding is that TN generally emphasizes more on the negative classroom situations, whereas MWB highlights "feeling well" and "function well", which are inherently positive. The findings of this study offer insights for mathematical education and propose directions for future research suggestions on how TN influences strategies for values alignment.

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PP1-02

PROSPECTIVE TEACHER'S VIEW OF GENERATIVE AI IN MATHEMATICS

Yutaka Ohara
Gakushuin University, Japan, yutaka.ohara@gakushuin.education

The objective of this poster presentation is to elucidate prospective mathematics teachers' view of generative AI within the context of mathematics education. This study investigates the belief systems of 42 prospective mathematics teachers enrolled in Japanese universities, employing a mixed-methods approach that integrates questionnaire surveys and semi-structured interviews. Through correlation analysis, we examined the relationships among participants' epistemological views of mathematics, perspectives on mathematics education, and attitudes toward generative AI. The findings indicate that individuals who view mathematics as a practical tool and see mathematics education as focused on achieving results are more likely to support the use of generative AI in the classroom. When participants with such tendencies introduce generative AI into the classroom, mathematical thinking in the learning process might be undervalued.

Keywords: prospective mathematics teachers, belief systems, correlation analysis, generative AI

Back Ground

The rapid advancement of generative AI presents a significant challenge for contemporary school education, necessitating a critical examination of its pedagogical implications (Ohara,2023). Mathematics is a language, but it has been thought that it is a few compatible with Large Language Models, which use huge amounts of text data and advanced deep learning techniques (Ohara et al.2024). However, recently, fine-tuning has made it possible to provide advanced mathematical solutions, and it is time to seriously consider its use in mathematics education (e.g., Jiyou at al. 2024).

Purpose and Method

The study aimed to elucidate prospective mathematics teachers' view of generative AI within the context of mathematics education. For this purpose, a preliminary survey was conducted using a questionnaire to investigate the belief systems of 42 mathematics prospective teachers enrolled in university (undergraduate students). A correlation analysis was conducted to examine the relationships between the 4 mathematics perspective items, the 4 mathematics education perspective items, and the 5 generative AI perspective items in the questionnaire. Following this, they used a Think-Pair-Share method to discuss how generative AI (Chat GPT) can be used in teaching to improve students' understanding, using the example of proving that $\sqrt{2}$ is an irrational number. After discussion, 4 examinees were selected for semi-structured interview.

Results, Conclusion and Discussion

The results of preliminary survey indicated three main points: 1) There was a significant weak positive correlation between belief that "mathematical knowledge is already complete" and "Generative

AI is a tool that can take over their thinking" ($r = .13$, $p < .01$), 2) there was a moderate negative correlation between belief that "mathematical knowledge is a tool for problem solving" and "Generative AI is an egalitarian interlocutor with humans" ($r = -.38$, $p < .01$), and 3) the belief that "original thinking is not necessary for teaching mathematics" was significantly and positively correlated with their belief that "generative AI should be actively used in school classes" ($r = .41$, $p < .01$). These results suggest that beliefs about mathematics and its teaching might contribute to the use of generative AI in mathematics education.

In the interview session, it was shown that these beliefs were expressed through the activity of proving that $\sqrt{2}$ is an irrational number. The subjects (pair) suggested the active use of generative AI in the classroom, saying that mathematics is a thinking tool and students should use it to study on their own. Another pair argued that students should learn how to prove things correctly by contradiction using generative AI, since it is difficult for them to come up with their own proofs. These findings suggest that prospective mathematics teachers who regard mathematics as a practical tool and prioritize results in math education are more likely to endorse generative AI in classrooms. Whether these conclusions can be verified through qualitative research is open to discussion, and further practical investigation is required.

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PP1-03

BLENDED LEARNING STATION ROTATION MODEL AND STUDENTS' ENGAGEMENT IN MATHEMATICS LEARNING

Rashidah Vapumarican
CHIJ Kellock, Singapore, arif_hong_chu_sen@moe.edu.sg

Helen Teo Hai Loon
CHIJ Kellock, Singapore, helen_teo_hai_loon@moe.edu.sg

Kavitha Rajendran
CHIJ Kellock, Singapore, kavitha_rajendran@moe.edu.sg

Introduction

This study is on student engagement using blended learning station rotation model (SRM) to promote active learning in mathematics among primary school students. Student engagement is a critical aspect in learning. It is not only an indicator of students' positive functioning, but also forecasts highly valued outcomes, such as students' academic progress and achievement (Fredricks et al.,2004). The study analysed three dimensions of student engagement; namely cognitive, emotional and social engagements. Cognitive engagement is the readiness to put in effort to understand content, focus and manage given tasks and work through difficult problem (Finn & Zimmer, 2012). Emotional engagement is the presence of positive emotional reactions to teachers, peers, and the classroom activities, valuing learning and having interest in the learning content (Finn, 1989; Voelkl, 1997). Social engagement includes the quality of social interactions with peers and adults, preparedness to invest in the development and maintenance of relationships in the process of learning (M.T. Wang et al., 2016). The teachers used SRM to create individual and small learning communities within the larger class setting, design various learning tasks including differentiated tasks, that allow students to engage with information in different modalities (Tucker C. R., Wycoff T., & Green J.T., 2017).

Methodology

Participants

64 students from two classes of Primary 3 (P3) who are of middle (MP) to low progress learners (LP) and 77 students from three classes of Primary 6 (P6) who are of high (HP) to LP learners.

Intervention

The study was conducted using blended learning SRM (Fig. 1). It was carried out as part of revision across several topics before the end of year examination for P3 students and Primary School Leaving Examination (PSLE) for P6 students.

Instrument

Data on student engagement was collected using a 4 point-likert scale questionnaire (Fig.2) adapted from student engagement mathematics scale (Rimm-Kaufman et al., 2014). An open-ended question was also collated to better understand students' engagement. These were administered immediately after the intervention.

Figure 1. Station Rotation Model (SRM)

No	Statement	SA	A	D	SD
1	I tried my best during maths class today.				
2	I had the opportunity to discuss with my classmates in maths class today.				
3	I had the opportunity to help my classmates in doing math tasks today.				
4	I had the opportunity to share my thoughts and ideas with my classmates in math class today.				
5	I can see my classmates helped one another learn in maths class today.				
6	Maths lesson was fun today.				
7	I felt bored in maths lesson today.				
8	I enjoyed thinking about maths today.				
9	I was able to understand and do the maths tasks well today.				
10	I tried to learn as much as I could in maths lesson today.				
11	Learning maths was interesting to me today.				
12	I liked the feeling of solving problems in maths today.				
13	I did a lot of thinking in maths lesson today.				
Please write what else you feel about the maths lesson today:					

Figure 2: Student Questionnaire

Findings

Table 1: P3 Responses to Engagement

		SA	A	D	SD
Cognitive	Total No.	181	69	6	0
	%	70.7	27.0	2.3	0
Emotional	Total No.	243	71	3	4
	%	75.7	22.2	0.9	1.2
Social	Total No.	179	74	4	0
	%	69.6	28.8	1.6	0

Table 2: P6 Responses to Engagement

		SA	A	D	SD
Cognitive	Total No.	127	170	11	0
	%	41.2	55.2	3.6	0
Emotional	Total No.	191	164	28	2
	%	49.6	42.6	7.3	0.5
Social	Total No.	148	141	18	0
	%	48.2	45.9	5.9	0

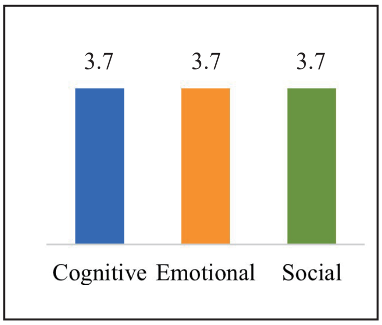

Figure 3. P3 Overall MRI

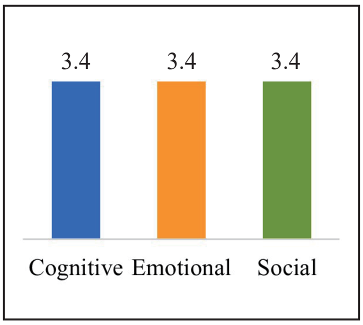

Figure 4. P6 Overall MRI

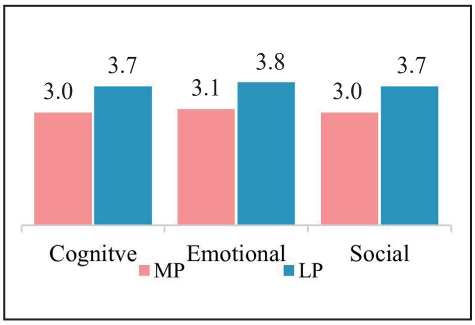

Figure 5: P3 MP vs LP

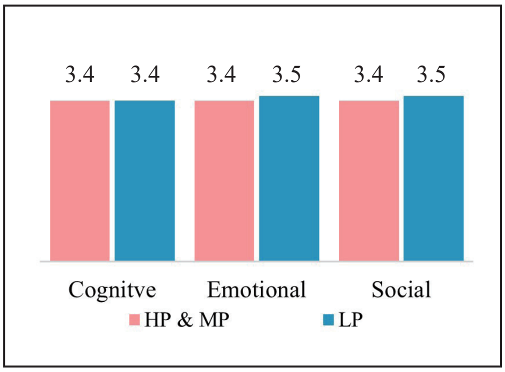

Figure 6: P6 HP &MP vs LP

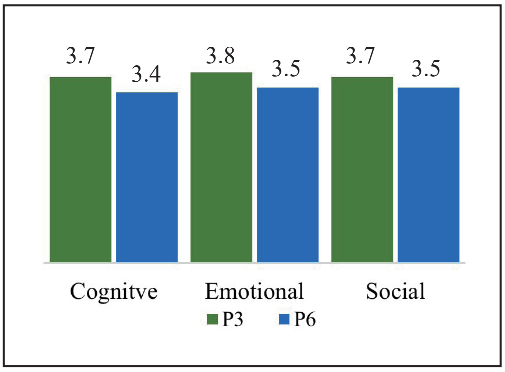

Figure 7: P3 LP vs P6 LP

Discussion

The findings for both P3 and P6 students showed a high level of engagement in all three dimensions; cognitive, emotional and social with percentages above 90% (SA and A) and MRI of 3.4 and above. P3 students however, showed a higher overall MRI of 3.7 as compared to P6 MRI of 3.4. When comparing the engagements of the different types of learners, P3 LP learners showed higher level of engagements during SRM compared to P3 MP learners. A small difference in MRI can be observed for the P6 students between HP, MP learners and LP learners. Findings from P3 LP and P6 LP learners showed that the P3 LP learners are more engaged in their learning during SRM in comparison to the P6 LP learners.

The different designed tasks in SRM allows teachers to meet the different learning needs of the students in the class by offering them different modalities of learning, including various modes of interactions; individual, in pairs and small groups. SRM empowers teachers to create differentiated tasks as well as addresses the issue of balance in utilising online tasks and offline tasks in teaching and learning. The affordance of technology enables students to get immediate feedback during the learning process. Students are given the platform to interact and collaborate with their peers and learn from one another through coaching. While coaching others, students tend to internalize the mathematics concepts better. In addition, SRM provides opportunity for teachers to engage students on a one-to-one interaction especially for students who need the individual time and attention.

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PP1-04

DEVELOPMENT AND ANALYSIS OF MATHEMATICS MOTIVATION SCALE FOR ELEMENTARY SCHOOL STUDENTS

Yuan-Horng Lin

National Taichung University of Education, Taiwan, lyh@mail.ntcu.edu.tw

Ching-Wen Tseng

National Taichung University of Education, Taiwan, ama110132@gm.ntcu.edu.tw

Motivation is one of the non-cognitive factors that influence learning. Most studies on mathematics motivation focus on university or secondary school students. There is a lack of Chinese version mathematics motivation scale specifically designed for elementary school students. Therefore, the purpose of this study is to develop Chinese version mathematics motivation scale suitable for elementary school students and to investigate differences in motivation factors among students with demographic variables. The study identifies three factors for mathematics motivation: interest-cost, importance-utility, and self-efficacy. The Cronbach's α for the three factors are .850, .879, and .907 respectively. Significant differences are found between male and female students in interest-cost and self-efficacy. Male students are significantly higher than female students. Additionally, there are significant differences across all three factors between middle-grade students (third and fourth grades) and upper-grade students (fifth and sixth grades). The above findings provide insights into the performance and characteristics of elementary school students in mathematics motivation. The mathematics motivation scale developed in this research can serve as references for future studies.

Keywords: mathematics affect, mathematics motivation, motivation

Introduction

Mathematics affect encompasses beliefs, attitudes, motivation, and emotions and motivation influences learning goals and values (Anderman & Wolters, 2006; Zan, Brown, Evans, & Hannula, 2006). Ramos, Sixte, Janez, and Rosales (2022) develop Spanish version of the ESMS-E scale. Most motivation assessment tools and research focus on high school and college students. However, little is known about Chinese version of mathematics motivation scale for elementary school students. This study has the following objectives: (1) Develop Chinese version of mathematics motivation scale suitable for elementary school students. (2) Analyze the differences in mathematics motivation based on grade and gender.

Literature Review

There are many theories related to motivation. These theories include Self-Determination Theory (Ryan & Deci, 2000), Expectancy-Value Theory (Wigfield & Eccles, 2000), Social Cognitive Theory, Attribution Theory, and Achievement Goal Theory. This study reviews and synthesizes literature and measurement scales on mathematics motivation (Arellano-García, Vargas-De-León, Guzmán-Martínez, and Reyes-Carreto, 2022; Ramos, De Sixte, Jáñez, and Rosales, 2022; Orosco, 2016; Sousa & Silva, 2021). From this review, five dimensions of mathematics learning motivation are selected, which are interest, importance, utility, cost, and self-efficacy.

Research Design

Based on the literature review above, this study adopts five-point Likert scale. Exploratory factor analysis is adopted to decide number of factors based on the criterion of eigenvalues greater than 1. After analyzing the pre-test data using exploratory factor analysis, this study confirms three factors. it is found that due to cultural context, students perceive interest and cost as the same factor, as well as importance and utility. Consequently, the three factors are primarily interest-cost, importance-utility, and self-efficacy. The definitions of each factor are shown in Table 1.

Table 1 Names and definitions of each factor

Factor	Definitions
interest-cost	Having interest in learning mathematics and paying attention, with a willingness to spend time and effort studying mathematics
importance-utility	Believing that learning mathematics is important and meaningful, with practical application value
self-efficacy	Believing in one's ability to learn mathematics well and achieve goals

Results and Discussions

The sample involve 350 students from Taiwan. The total variance explained by three factors is 67.22%, and the overall Cronbach's α value for the scale was 0.935. Table 2 provides details on the number of items, reliability, and variance explained for each factor.

Table 2 Validity and reliability of the Mathematics Motivation Scale

Factor	Number of items	Mean	Cronbach's α	Explained variance
interest-cost	5	2.37	.85	20.99%
importance-utility	6	3.50	.88	22.68%
self-efficacy	5	3.26	.91	23.55%

As shown in Table 3, there are significant differences in the interest-cost and self-efficacy factor between male and female students.

Table 3 Mean difference test by gender

Factor	Gender	Mean	Standard deviation	t
interest-cost	male	2.46	1.02	2.33^{*}
	female	2.25	.86	
importance-utility	male	3.60	1.04	1.72
	female	3.41	1.00	
self-efficacy	male	3.50	1.17	4.04^{***}
	female	3.01	1.08	

**p*<.05 ****p*<.001

Table 4 presents the mean difference tests by grades. Overall, the results show a trend where middle-grade students (grades 3 and 4) are higher than upper-grade students (grades 5 and 6).

Table 4 Mean difference tests by grade

Factor	Grade	Mean	Standard deviation	F	Post-hoc comparisons
interest-cost	3	2.58	.90	8.00^{***}	grade 3 > grade 6 grade 4 > grade 6
	4	2.59	.91		
	5	2.58	.93		
	6	2.03	.96		
importance-utility	3	3.89	.86	17.55^{***}	grades 3 and 4 > grades 5 and 6
	4	3.80	.87		
	5	3.35	1.07		
	6	3.01	1.04		
self-efficacy	3	3.77	1.03	15.21^{***}	grade 3 > grade 5 grade 3 > grade 6 grade 4 > grade 6
	4	3.45	1.04		
	5	3.22	1.15		
	6	2.73	1.15		

***p<.001

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PP1-05

EVALUATION OF MATHEMATICS CLASSROOM INSTRUCTION IN THE ERA OF ARTIFICIAL INTELLIGENCE

Yiming Cao

Beijing Normal University, China, caoym@bnu.edu.cn

Wenjun Zhao

Sichuan Normal University, China, zhaowj6616@sicnu.edu.cn

This study explores the use of artificial intelligence (AI) technology to evaluate the quality of mathematics classroom instruction, aiming to addresses existing gaps in classroom instruction research, such as high subjectivity in coding, low analytical efficiency, and challenges in scalability. The research develops an evaluation system that incorporates instructional behaviors, language, and emotional characteristics. An intelligent evaluation system is created to automatically assess the quality of mathematics classroom instruction, providing data and reports to aid in teachers' professional development. The findings contribute to the development of a database and framework for evaluating the quality of classroom instruction, offering valuable insights for educational policy-making, teacher training, and large-scale research on classroom instruction.

Research Background

International comparison studies, such as TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment), show significant variations in student academic achievement across countries, with students from Asia, including China, consistently performing at the top levels (Mullis et al., 2020; Schleicher, 2019). Researchers generally agree that classroom instruction is a key factor influencing students' academic performance, which has led to a series of large-scale international comparative studies on classroom instruction, including TIMSS video study (Stiger & Hiebert, 1996) and the Learners' Perspective Study (Clarke, Keitel, & Shimizu, 2006). Both studies provide quantitative and qualitative descriptions of classroom instruction features across various countries, focusing on dimensions such as content, language, structure, and teacher-student dialogue, while also exploring the characteristics of high-quality classroom instruction. These studies have also introduced the method of video-based classroom instruction analysis, marking a significant milestone. However, recent research has highlighted several limitations of video-based classroom instruction analysis, including the single data format, emphasis on form over content, high subjectivity in coding, low analytical efficiency, and challenges in scalability (Sun et al., 2020), which hinder in-depth exploration of educational principles. The rise of artificial intelligence (AI) technology offers unprecedented opportunities to address these issues.

In this context, the present study aims to explore how to apply AI technology for multimodal intelligent evaluation of mathematics classroom instruction. It seeks to construct an evaluation index system for mathematics classroom instruction quality by analyzing large-scale classroom videotapes, to accurately diagnose and improve the quality of classroom instruction.

Related Research

Research on Evaluation of Classroom Instruction Quality

In the 1970s, with the rise of quantitative analysis in classroom instruction, numerous classroom instruction evaluation frameworks emerged. Representative models include the IRF (Initiation-Response-Feedback) interaction model proposed by Sinclair and Coulthard (1975), the Flanders Interaction Analysis System (Flanders, 1970), S-T analysis (Cheng et al., 2016), and the CLASS system for classroom observation coding (Pianta et al., 2008).

Instructional behaviors have been a common focus in existing classroom instruction evaluation frameworks. However, these frameworks exhibit issues such as a variety of evaluation dimensions, inconsistent classification standards, and difficulty in making the results comparable. To address these problems, Cao and his colleagues proposed the concept of key instructional behaviors (Cao & Yu, 2017) , confirming through international comparative studies that this concept could serve as an important aspect for classroom instruction evaluation. Key instructional behaviors refer to those that significantly contribute to the efficient and orderly functioning of the classroom and the students' acquisition of knowledge. The research team identified 16 key instructional behaviors from 126 instructional behaviors, including teacher-student interaction, teacher questioning, teacher explanation, student questioning, and cooperative learning (Cao & Yu, 2017).

Moreover, some researchers argue that existing evaluation frameworks overly focus on the form of classroom instructional behaviors, such as frequency, duration, and sequence, while insufficiently addressing the content and function of these behaviors. Consequently, some research teams have developed evaluation frameworks focusing more on instrucitonal language. Notable frameworks include the classroom dialogue coding system developed by the Cambridge team in the UK, which analyzes discourse types aimed at fostering higher-order thinking, such as reasoning, elaboration, querying, coordination, referring back, and referring widely (Webb, Franke, & Ing, 2019). Through a comparative analysis of classroom dialogue coding systems over the past decade, Song (2021) established a framework for analyzing classroom dialogue that focuses on students' higher-order thinking development, which includes factual discourse, personal information sharing, reasoning, coordination, and inference discourse.

Further, some researchers argue that instructional emotions are also important components of classroom instruction. Hargreaves (1998) emphasized that teaching is not only about knowledge transmission, but also about emotions, which play a central role in teaching. For instance, teachers' emotions largely influence their behaviors, such as facial expressions, tone of voice, gestures, and actions (Hargreaves, 1998). Qu (2014) shows that outstanding teachers tend to manage their emotions more effectively, and those with excellent emotional management are better at handling classroom tasks, leading to better teaching outcomes.

In summary, this research proposes that classroom instructional behaviors, language, and emotional characteristics are key indicators of classroom instruction quality. A comprehensive evaluation that considers these three dimensions and their interactions will provide a more well-rounded assessment of classroom instruction quality.

AI-Based Classroom instruction Analysis

A number of studies have been conducted in the field of AI-based classroom instruction analysis. For example, the Columbia University team used video emotion analysis, facial detection, and posture analysis technologies to analyze learners' emotional states (Bosch et al., 2016); the Nanyang

Technological University team developed an automatic system for evaluating classroom atmosphere (James, 2018); Song (2021) used natural language understanding technology to automatically identify and categorize teacher-student dialogue in classrooms, achieving high accuracy. Xu, Deng and Wei (2020) used classroom teaching videos to automatically collect and label five types of student behaviors, including listening, reading, standing, raising hands, and writing.

Despite these advancements, there are still several limitations in AI-based classroom instruction analysis: (1) Most analyses of classroom language and behavior focus on forms, such as frequency and duration, rather than the deeper meaning and implications behind teaching behaviors; (2) Research on classroom emotions mainly focuses on students' emotions, with little attention given to teachers' emotions, which should be an integral part of the classroom instruction evaluation; (3) Most studies focus on technical aspects and lack educationally meaningful goals and frameworks.

This study aims to address these four limitations by conducting empirical research rooted in real classrooms, exploring the underlying meanings and patterns of classroom events, and integrating teachers' emotions into the evaluation framework.

Main Work of the Study

In light of these issues, this study has been committed to advancing the professionalization, intelligence, and scalability of classroom instruction quality evaluation through AI technology.

Development of the Classroom Instruction Qaulity Evaluation Framework

To address the issues in existing evaluation frameworks, we have created an index system guided by international and national important official documents on future student development. Using quantitative research methods, we have extracted core indicators from complex texts and existing evaluation frameworks, ensuring that these indicators are comprehensive, universal, and practical. Through systematic verification by experts in mathematics education and extensive coding tests of mathematics lessons, we have refined the operational definitions of these indicators to ensure clarity and precision in coding categories and terms. Ultimately, we have constructed an evaluation index system that covers the dimensions of behavior, language, and emotions. Indicators of behaviors include explanation, presentation, questioning, responding, feedback and classroom management; indicators of language oriented towards the development of students' key competencies, such as learning comprehension, expression and communication, practical application, and critical thinking and innovation; indicators of classroom emotion include classroom emotion such as positive, negative and neutral, and teacher-student attention.

Introduction to the Intelligent Evaluation System for Classroom Instruction Quality

Since the early 2000s, our team has been deeply involved in classroom instruction evaluation. We have evolved from manual coding to human-machine collaboration and now to fully automated analysis. In terms of model training, we explored both small and large models. While small models are stable and suitable for large data sets, their accuracy in complex indicator labeling is limited. Large models, on the other hand, require fewer initial data, and offer flexibility in modifying indicators. After comprehensive evaluation, we selected the large model as our preferred solution.

In collaboration with iFLYTEK, we developed an AI-based evaluation system for mathematics classroom instruction quality. Teachers can upload classroom teaching videos, and the system automatically analyzes them, providing scores and data across various dimensions, along with a detailed analysis report. This innovative tool enables teachers to quickly understand their teaching performance and implement targeted improvement strategies.

Figure 1. The Intelligent Evaluation System for Classroom Instruction Quality

The Application of Enhancing Teachers' Instructional Proficiency

At present, the team has developed a comprehensive video database containing thousands of classroom instruction videorecordings from primary, middle, and high school teachers and established evaluation norms and standards for assessing teachers' instructional proficiency. This provides a solid theoretical and practical foundation for improving the teaching skills of both pre-service and in-service teachers. After three years of practical validation, the system has been demonstrated to deliver efficient, precise, and targeted feedback on teachers' classroom pactices, achieving significant outcomes in supporting teachers' professional development.

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PP1-06

THE ROLE OF METACOGNITION AND INTELLECTUAL NEED FOR MATHEMATICAL ACTIVITIES

Daiki Kuroda
Gifu Shotoku Gakuen University, Japan, dkuroda@gifu.shotoku.ac.jp

Hisae Kato
Hyogo University of Teacher Education, Japan, katohi@hyogo-u.ac.jp

Keiichi Shigematsu
Professor Emeritus, Nara University of Education, Japan, shigekhome@gaia.eonet.ne.jp

Background and Purpose of This Study

Mathematical activities are extremely important in mathematics learning (MEXT, 2018). In addition, students must have intellectual need to engage in mathematical activities. However, Harel (2013) pointed out, "Most students, even those who desire to succeed in school, are intellectually aimless in mathematics classes because often they do not realize an intellectual need for what we intend to teach them." This highlights that learners' intellectual need has not been sufficiently aroused in mathematics classes to date. Therefore, the purpose of this study is to clarify the role of metacognition and intellectual need for mathematical activities through the analysis of mathematics classroom practices.

Overview of Class Analysis

To achieve the purpose, we analyzed the fourth-grade elementary school classroom practices titled 'How to Change' based on the study of metacognition (Shigematsu,1994) and the study of intellectual need (Harel,2013; Table 1). The following interaction is based on the task, "Let's use all 14 sticks to create various rectangles," this scene shows students creating different shapes of rectangles and sharing their observations.

Teacher: Have you ever noticed this? (Metacognitive question)

Student A: If you add up all the vertical and horizontal lines and then double the result, you get the total number of sticks.

Student B: The total number of sticks is obtained by adding 3 and 4, then doubling the result.

Student C: Then in that case… in that case...

Teacher: Yes, go ahead, C.

Student C: If you do $3 \times 4 = 12$, and then add 2, it becomes 14.

Student D: Not all of them. (Cognitive conflict)

Student D: If it's $1 \times 6 = 6$, and you add 2, it becomes 8, so it's only 8. (Need for certainty)

From this exchange, we can see that the teacher's metacognitive questions generate a variety of ideas for the learners. Furthermore, it becomes evident that the teacher's metacognitive questions trigger learners' cognitive conflict, such as a sense of confusion, which subsequently leads to the need for certainty.

Table 1. Intellectual Need (Harel,2013)

Categories of Intellectual Need	Detail
Need for certainty	The need for certainty is the need to prove, to remove doubts.
Need for causality	The need for causality is the need to explain— to determine a cause of a phenomenon, to understand what makes a phenomenon the way it is.
Need for computation	The need for computation includes the need to quantify and to calculate values of quantities and relations among them by means of symbolic algebra.
Need for communication	The need for communication consists of two reflexive needs: the need for formulation—the need to transform strings of spoken language into algebraic expressions—and the need for formalization—the need to externalize the exact meaning of ideas and concepts and the logical justification for arguments.
Need for structure	The need for structure includes the need to reorganize knowledge learned into a logical structure.

Conclusion

It is important for teachers to ask metacognitive questions to draw out various ideas from learners and enable them to engage in mathematical activities. Furthermore, it is also essential for teachers to ask metacognitive questions that trigger cognitive conflicts in learners. These efforts contribute to eliciting learners' intellectual need.

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PP1-07

AFFORDANCE OF PROGRAMMING FOR INTRODUCING TRIGONOMETRIC FUNCTIONS

Chung Man Koo

Hong Kong Taoist Association the Yuen Yuen Institute No.2 Secondary School, Hong Kong SAR, yy2kcm@web.yy2.edu.hk

Oi-Lam Ng

The Chinese University of Hong Kong, Hong Kong SAR, oilamn@cuhk.edu.hk

Huiyan Ye

The Chinese University of Hong Kong, Hong Kong SAR, huiyanye@link.cuhk.edu.hk

Keywords: Computational Thinking, STEM, programming, trigonometry

Introduction

STEM (Science, Technology, Engineering and Mathematics) education has been considered as key areas for students to manage future challenges in the 21st century; it encourages students to integrate knowledge from the four domains to solve real-life problems. Researchers highlight that an inter- disciplinary approach to mathematics education promotes non-traditional learning outcomes like problem-solving skills (Williams et al., 2016), that are hardly addressed by exam scores. Among the studies in STEM education, an increasing attention in the idea of computational thinking (CT) is observed. From the early mentioning of Wing (2006, pp. 33–35), CT is regarded as "thinking like a computer scientist", not necessarily related to the proficiency of using computer. In this poster, we designed a CT-based mathematics lesson to introduce trigonometric functions in a block-based programming environment.

Conceptual Framework of the Study

Beyond Wing's (2006) popularization of the term CT, researchers have studied and define different CT with various interpretations, including the close relationship among CT, mathematics, and problem-solving. In this poster, we adopt the CT heuristics provided by Ye at el. (2023) from their systematic review on CT-based mathematics instruction as the conceptual framework of the study.

Table 1: Summary of computational concepts (taken from Ye et al., 2023, pp. 14)

CT Concepts	Definition in the reviewed literature	CT Concepts	Definition in the reviewed literature
(1) Variables	An entity that can store, retrieve, and update values	(5) Sequences	The sequence or structure of instructions that should be followed to complete a goal; or a series of individual steps or instructions to be executed by the computer
(2) Conditionals	Instructions that either perform an action or not, according to a given condition		
(3) Loops	The control structure that makes it possible to repeat one or more sequences multiple times	(6) Events (handling)	Handle one thing that causes another to happen; and Instructions that make it possible to interact with objects in the programming environment
(4) Operators	Provide support for mathematical, logical, and string expressions	(7) Subroutines	A procedure that can be called within another procedure

Design of the Lesson

To utilize the affordances of CT heuristics to teach and learn mathematics, a lesson for grade 10 students (*n*=29, divided into 14 groups of 2 to 3) on introducing and graphing sine and cosine function was designed. The lesson was inquiry-based, starting with a real problem prompting students to describe, on paper, how a tennis ball moves along a string when pivoted at a centre. The teacher (first author) then guided the students to draw the motion of the ball in a block-based programming platform, *Scratch*. By reading the position in different time points (Figure 1a), the students used the programming function, lists (Figure 1b), to create the graph of the ball's vertical (and then horizontal) displacement as a function of the angle made between the string and the horizon (Figure 1c), which corresponded to the sine and cosine graph respectively. The lesson was recorded from the back of the classroom; screen and voice recording, as well as written worksheets were collected for analysis.

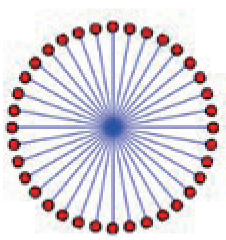

Figure 1a. Positions of a ball

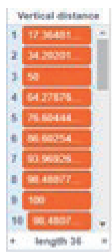

Figure 1b. List of vertical displacements

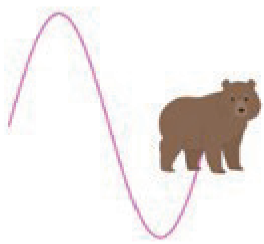

Figure 1c. Sine graph

Results and Discussion

Aiming to explore the affordances of programming and the design of CT-based mathematics instruction on student learning, our qualitative analyses suggested that the students responded to the physical context of the problem by making sense of the vertical and horizontal displacement of the ball, as well as what the program was to achieve. The students' programming codes showed that they could successfully utilize loops and sequences to instruct a character onscreen to move, which potentially facilitated a dynamic and geometrical representation of trigonometric functions. To do so, the students divided a full turn into *n* partitions so that they could program the ball to rotate 360/*n* degrees each time and to record the positions of ball into a list with the use of *n* loops. A dynamic notion was achieved by considering the steps of rotating the ball. Meanwhile, proficiency in using variables was also observed; some students described the list of *n* variables to explain the motion by *n* different instances, in which the abstraction supported their functional thinking that each (co)sine value corresponds to one angular displacement. However, due to lack of programming skills in event handling, many students failed to introduce a for-loop count to draw the required graphs within *Scratch*. In conclusion, the affordances for the lesson were twofold: it afforded a concrete and experimental approach to construct the graph of (co)sine through testing and debugging, and it supported a dynamic notion of angle turn, through which the (co)sine functions are created dynamically with loops, sequences and set of variables. Finally, we suggest that more training to help students overcome programming challenges (e.g. event handling) is needed to fully support CT-based mathematics instruction.

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PP1-08

HOW PRE-SERVICE TEACHERS DEVELOP LESSON PLANS USING CHATGPT

Sunghwan Hwang
Chuncheon National University of Education, South Korea, shwang@cnue.ac.kr

Introduction

Lesson planning serves as a blueprint for instruction, allowing teachers to structure and deliver lessons effectively (Lloyd et al., 2017). However, pre-service teachers often struggle with this process due to their limited knowledge and experience. In response to these challenges, researchers have explored the use of ChatGPT as a tool to support pre-service teachers in lesson planning (Karaman & Göksu, 2024). ChatGPT not only provides relevant knowledge through its search and generative capabilities but also serves as a collaborative partner in structuring and refining lesson plans (Farrokhnia et al., 2024; Karaman & Göksu, 2024). For ChatGPT to be effectively integrated into education, it is crucial to conduct a systematic analysis of pre-service teachers' experiences, including the benefits and challenges they encounter. Thus, this study investigates how pre-service teachers use ChatGPT in designing lesson plans using activity theory. This study also analyzes the constraints they face and the strategies they use to overcome these limitations.

Methods

The study involved 83 Korean pre-service elementary school teachers. Participants worked in small groups of three to four members over two weeks to design a lesson plan for teaching the addition of fractions with different denominators. They were provided mathematics textbooks, teacher guides, sample lesson plans, and information on students' mathematical problem-solving abilities. Upon completing the development of lesson plans, each participant submitted a reflective journal documenting their experiences. To analyze the interaction between pre-service teachers and ChatGPT, all conversation logs were transcribed and categorized sequentially based on the order of prompts and responses. Then, relevant excerpts were then coded according to Activity Theory elements (Engeström, 2014; Guo et al., 2024). Key constructs included the subject (pre-service teachers), object (lesson planning objectives), and tool (ChatGPT as a digital assistant). This study also examined the interrelationships between Activity Theory elements, particularly focusing on contradictions, constraints, and strategies for overcoming ChatGPT's limitations.

Findings and Conclusions

The findings revealed that pre-service teachers structured their lesson plans by adhering to curriculum guidelines while distributing roles among group members. ChatGPT was utilized as a tool to develop lesson plans. Three key phenomena emerged. The first was the constraint of rule-based thinking, where curriculum standards acted as rigid guidelines that shaped the nature of ChatGPT prompts and influenced how participants used the tool. The second was over-reliance on AI-generated content, as some participants unquestioningly trusted ChatGPT's responses and incorporated incorrect information into their lesson plans. The third was the reification of the tool, where some participants engaged with ChatGPT as if the act of filling in the blank in the lesson plan templates was the ultimate goal rather than using it as a supplementary resource.

Participants who relied exclusively on ChatGPT failed to develop effective lesson plans, whereas those who engaged in transformative learning by recognizing AI's limitations and employing alternative strategies successfully designed more comprehensive lesson plans. These findings align with previous research, suggesting that overcoming contradictions through reflection leads to improved teaching strategies (Guo et al., 2024). This study highlights the critical role of self-awareness and problem-solving strategies in AI-assisted lesson planning. The findings suggest that while ChatGPT can serve as a valuable pedagogical tool, its effectiveness depends on pre-service teachers' ability to critically engage with AI-generated content and integrate additional educational resources (Farrokhnia et al., 2024; Karaman & Göksu, 2024). Teacher education programs should incorporate AI literacy into pre-service teacher training to promote critical evaluation of AI-generated content. Schools and teacher education institutions should provide professional development opportunities that help teachers effectively integrate AI into their instructional design.

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PP1-09

DESIGNING GRAPHING TASKS FROM THE GROUND UP

Hwa Young Lee
Texas State University, U.S., hylee@txstate.edu

Teo Paoletti
University of Delaware, U.S., teop@udel.edu

Hamilton Hardison
Texas State University, U.S., hhardison@txstate.edu

Brandi Rygaard Gaspard
Texas State University, U.S., brr102@txstate.edu

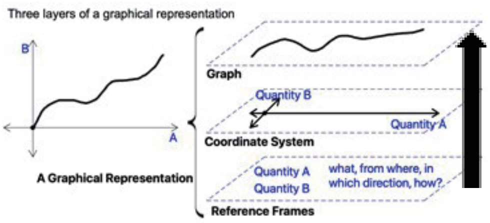
Mai Bui
Texas State University, U.S., mtb104@txstate.edu

Holly Zolt
Middle Tennessee State University, U.S., Holly.Zolt@mtsu.edu

Keywords: Graph literacy, graphing tasks, task design, design-based research

Graphical representations are common in STEM fields for modeling, communicating, and analyzing phenomena. Results from research (e.g., Lai et al., 2016), including large-scale national assessments (e.g., Nation's Report Card, 2005), indicate that U.S. students have not been provided sufficient opportunities for developing rich graphing understandings. However, much of the research and tasks used to examine students' graphing understandings have assumed that students have established understandings of the Cartesian plane needed to construct and interpret graphs. In our work, we address this issue by designing tasks that attend to students' understandings of three layers constituting a graphical representation: reference frames (RFs), coordinate systems (CSs), and graph (Joshua et al., 2015; Lee et al., 2020) (see Figure 1a).

RFs are mental structures used to gauge the relative extents of various attributes in the phenomenon being depicted (Levinson, 2003; Lee, 2017). Thinking within RFs entails attending to and establishing reference points, directionality, and having an idea of what and how to measure the quantities being depicted (Joshua et al., 2015; Lee et al., 2020). CSs are the geometric embodiment of the RFs (e.g., axes) that allow an individual to systematically express and coordinate RFs. Finally, a graph is a collection of points depicted upon the underlying CS. The ways of thinking about a graph fundamentally depends on the RFs and CSs upon which they are created.



(a)

Task Design/Re-Design Guiding Questions	
1. Reference Frames (RFs)	1.1. Is the task situated in (what we perceive to be) a spatial or quantitative context? 1.2. What features of the task will/did support students in identifying (a) a reference point, (b) a directionality, and (c) a unit of measure?
2. Coordinate Systems (CSs)	(All of the questions above and) 2.1. Is the task situated in (what we perceive to be) a spatial or quantitative context? 2.2. What features of the task will/did support students in coordinating two or more RFs to construct a spatial/quantitative CS?
3. Graphs	(All of the questions above and) 3.1. Is the graph situated in (what we perceive to be) a spatial or quantitative CS? 3.2. What features of the task will/did support students in constructing or interpreting graphs in a spatial/quantitative CS?

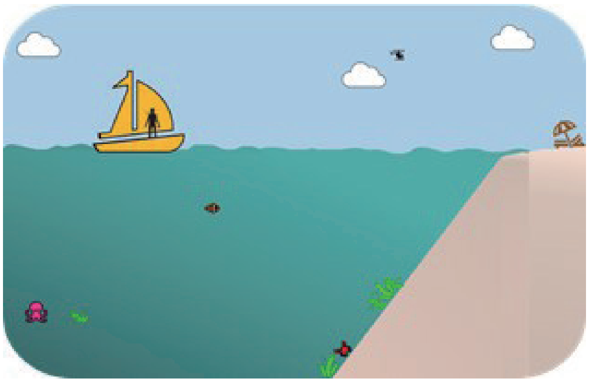
(b)

Figure 1. (a) Three layers of a graphical representation and (b) our task design framework

In this poster, we illustrate how this novel framework was used to design a graphing task, namely, the Deep Sea Diver Task (see Table 1), for middle-grades students (Grades 5–8 in the U.S.).

Table 1. The Deep Sea Diver Task

Task Prompt

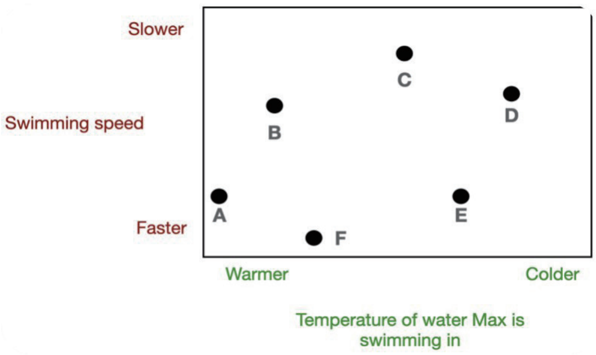


1. Max cannot see the sea creatures from his boat. Only you can see this picture. Describe the location of the octopus, fish, and crab for Max.

2. Max leaves his boat and starts to swim. First, he swims deeper into the water while also swimming further from the shore. Next, he swims closer to the shore while staying the same depth below the water. Finally, Max continues to swim closer to the shore while decreasing his depth. Draw a possible path Max swam in this story.

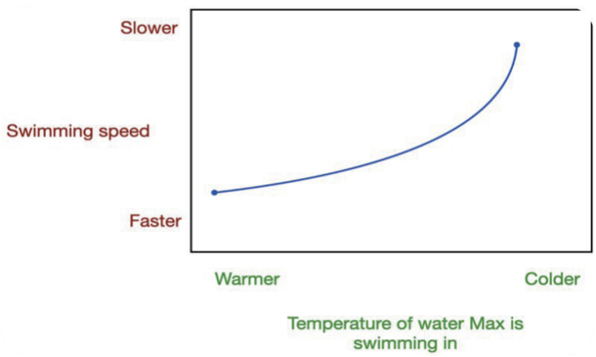
3. Assume Max swam on the path you drew. At first Max hits the water swimming fast but slows throughout his entire swim. Max knows the deeper he goes in the water, the colder it gets.

a) Describe how water temperature and Max's swim speed change throughout his journey.
b) Create a drawing to explain how his speed and the water temperature changed together throughout his swim without using words.



4. The points A-F represent different temperatures and swim speeds Max experienced.

a) Which point shows the lowest water temperature? The highest water temperature?
b) Which point shows the highest swim speed? The lowest swim speed?
c) How does the water temperature and speed represented by point B compare to water temperature and speed represented by point E?



5. The sketch shows the relationship between the water temperature Max experienced and his swimming speed on a different swim.

- What does this sketch tell you about how these two quantities change together?
- Can you describe a situation that may have resulted in this sketch above?

We implemented the task in one-on-one clinical interviews (Clement, 2000; Goldin, 2000) with 27 sixth-grade students to gain insights into their initial graphing understandings at the onset of a teaching experiment (Steffe & Thompson, 2000) aimed at examining and building upon students' graphing understandings. We discuss affordances and limitations of our approach, as well revisions we made as a result of our analyses of students' activities.

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Acknowledgment

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PP1-10

ENHANCING JUNIOR HIGH SCHOOL STUDENTS' SELF-REGULATED LEARNING IN ALGEBRA THROUGH GENERATIVE AI: APPLICATION DEVELOPMENT AND PRELIMINARY FINDINGS

ChangHua Chen

National Changhua University of Education, Taiwan, cchen72@cc.ncue.edu.tw

ChiaHui Lin

National Taichung University of Education, Taiwan, ellen521@mail.nctu.edu.tw

Keywords: Algebra Learning, Four-Component Instructional Design, Generative AI, Self-Regulated Learning

Research Background and Objective

Recent generative artificial intelligence (GAI) advancements have shown significant potential in natural language processing and knowledge reasoning (Hamilton et al., 2023). Integrating GAI into mathematics education can offer personalized and immediate learning support, enabling students to receive timely feedback and guidance. However, an overreliance on GAI could hinder students' mathematical thinking and independent problem-solving skills. To address this issue and leverage the benefits of GAI, it is critical to develop instructional strategies and tools that promote students' self-regulated learning (SRL) skills in AI-assisted environments. SRL enables students to monitor and regulate their learning processes actively, thereby enhancing metacognition and sense of agency. Therefore, this study adopted a design-based research methodology (Barab & Squire, 2004) to iteratively develop and refine a mathematics SRL application that integrates GAI while explicitly supporting students' SRL skills. Additionally, we applied the Four-Component Instructional Design (4c/ID) (van Merriënboer et al., 2024) as a theoretical basis to integrate SRL components into the app's design, ensuring that learners engage in realistic and meaningful mathematical tasks. This research investigated how GAI can assist seventh-grade students in cultivating SRL within the context of algebraic problem-solving.

Research Methods and Tool Development

Tool Development

- The app was built using ChatGPT API and incorporated image recognition, text input, and speech output for diverse mathematical problem-solving interactions.
- Personalized prompts provided solution strategies, metacognitive questioning, and error detection when students struggled.

- Mathematics teachers collaboratively reviewed math tasks and solution logic to mitigate GAI-generated errors.

Implementation and Data Collection

- App Testing: Small-scale pilot testing in two selected classrooms to refine usability and feedback mechanisms.
- Teacher Professional Development: Five math teachers formed a professional learning community that co-designed AI-integrated teaching strategies, conducted lesson observations, and iteratively refined instructional approaches.
- Teacher interviews were conducted to learn the impacts of the app on students' math learning.

Preliminary Findings and Teacher Feedback

Differentiated Individualized Instruction

The participating teachers noted that AI-assisted instruction matched or exceeded traditional learning outcomes, benefiting students with varied learning needs. High-achieving students reduced redundant practice while struggling students received step-by-step guidance to overcome computational barriers.

Learning Motivation of Low-Achieving Students

Teachers observed that while GAI did not dramatically improve problem-solving skills, students exhibited greater willingness to attempt questions multiple times. Short teacher interventions following GAI guidance significantly improved response accuracy.

Differences in High-, Mid-, and Low-Achieving Students

- High-achieving students: Used GAI primarily for answer verification and error detection.
- Mid-achieving students: Struggled to utilize GAI for conceptual reconstruction, requiring additional teacher support.
- Low-achieving students: Followed GAI-generated step-by-step instructions effectively, demonstrating notable learning improvements.

Conclusion and Future Directions

Preliminary results indicated that when scaffolded by teachers, GAI can offer comparable or superior outcomes to traditional methods, particularly for low-achieving students. The study underscored GAI's role in providing differentiated instruction and real-time feedback, allowing teachers to focus on higher-order thinking and problem-solving strategies. However, mid-achieving students may require additional interventions to optimize AI-assisted learning. Future research will:

- Expand the app's task bank and scaffolding features for broader algebraic concepts.
- Investigate the teacher-AI-student interaction model by using learning analytics to track behavioral sequences and conceptual transitions.

- Conduct large-scale classroom-based studies to evaluate long-term effectiveness and policy implications.

Generative AI holds promise as a transformative tool in mathematics education. However, its success depends on well-designed instructional strategies and teacher assistance to promote SRL and deeper mathematical understanding.

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PP1-11

TASK MODIFICATION BY PRE-SERVICE MATHEMATICS TEACHERS: AN ANALYSIS FOCUSED ON DEFINITIONS OF GEOMETRIC SIMILARITY

Nam-Hyeok Im

Chungbuk National University, Korea, inh0628@naver.com

Sung-Jae Moon

Chungbuk National University, Korea, sungjaemoon88@chungbuk.ac.kr

Introduction

Despite its practical applications in daily life and significant role across various mathematical domains, geometric similarity has been identified in numerous studies (Kaput & West, 1994; Cox et al., 2007; *Özerem*, 2012) as a source of various epistemological obstacles and misconceptions among students. Lee and Lim (2005) specifically reported that teachers experience difficulties in applying geometric similarity in actual classroom instruction. To address these teaching and learning challenges, previous research (Lee et al., 2013; Kim & Lee, 2016) presents task modification as a means to promote students' conceptual understanding and realize curriculum objectives. By considering various teaching and learning aspects, these studies highlight task modification as an opportunity for teachers' professional development. Consequently, task modification offers a potential approach to overcoming difficulties associated with teaching and learning similarity.

However, there is a relative lack of research analyzing how mathematics teachers modify tasks to teach geometric similarity. Therefore, this study will present major issues in similarity along with reconstructed textbook tasks and examine how pre-service mathematics teachers consider similarity-related issues in their task modification process.

Theoretical Background

1. Issues in geometric similarity

1.1 Problems Arising from Everyday Usage of Similarity

According to Yu and Park (2019), while similarity is often explained through everyday expressions, students tend to accept it instrumentally rather than understanding it intuitively because the degree of similarity perceived varies from person to person in daily life For example, when a rectangle is stretched horizontally to half its original width, one student might still consider it similar to the original shape, while another student might argue that the significant change in proportion disqualifies it from being similar. This demonstrates how the perception of similarity can be subjective and dependent on individual interpretation of geometric transformations.

1.2 Two definitions of similarity of figures

According to Lim and Park (2009), there are two definitions of geometric similarity. With changes in curriculum, current textbooks adopt a Type 1 definition of similarity, which states that two figures are similar when one can be expanded or reduced to a certain ratio to become congruent with the other. However, to verify if two figures are similar using this definition, one must directly expand or reduce one figure to determine if it is congruent with the other. This process creates a dilemma where Type 1 definition assumes congruence without separate verification criteria, making it a cumbersome procedure.

2. Professional development through task modification

Following the discussion in prior research, this study defines task modification as a 'professional practice where teachers systematically reconstruct the context, conditions, and questions of existing tasks to develop their mathematics education expertise.' According to Lee, Park, & Lee (2013) and Prestage & Perks (2007), analyzing and modifying tasks is important because it contributes to teachers' and pre-service teachers' professional development. Task modification strategies include adjusting cognitive demand levels and modifying conditions, questions, and contexts.

Method

1. ***Research Subjects:*** 20 pre-service teachers from a mathematics education department at a university in Korea
2. ***Research Methods:*** Analyze cognitive demand levels using Smith & Stein's (1998) criteria, and apply Lee et al.'s (2013) analytical framework to examine major changes in task transformation process
3. ***Data Collection:*** Collect transformed tasks and conduct semi-structured interviews with 6 pre-service teachers selected from the top and bottom 5 students who demonstrated characteristic understanding of geometric similarity.

Partial Results

The analyzed pre-service mathematics teachers' task modifications on similarity of figures. Results showed: (1) 65% of teachers raised the cognitive demand levels; (2) Question modifications were most common (58.47%); (3) 65% addressed the "Type 1 definition dilemma" regarding similarity and congruence; (4) Teachers with stronger understanding of similarity created more effective tasks, demonstrating the connection between content knowledge and task modification skills.

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PP1-12

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN PISA 2022 TAIWANESE STUDENTS' CURIOSITY AND MATHEMATICAL LITERACY

Wan-Chih Shih

National University of Tainan, Taiwan, julie19990903@gmail.com

Su-Wei Lin

National University of Tainan, Taiwan, swlin0214@mail.nutn.edu.tw

Keywords: PISA ; Curiosity ; Mathematical Literacy

Research Motivation and Background

Mathematics is key to personal development and can cultivate logical thinking and problem-solving skills. Taiwan's education system views mathematics as the foundation of scientific learning. Research indicates that curiosity significantly impacts learning, as it can stimulate students' motivation and creativity. Dr. Martin Seligman emphasizes that curiosity brings psychological satisfaction (Seligman, 2002). According to Loewenstein's knowledge gap theory, curiosity is triggered when individuals perceive a lack of knowledge. Curiosity can be divided into trait and state curiosity, with the former being stable and long-lasting, while the latter being temporary and context-dependent (Loewenstein, 1994). Gruber et al. (2014) suggest that highly curious students tend to excel academically.

Furthermore, socioeconomic status, gender, and grade level differences also influence the development of curiosity and mathematics performance. Families with higher socioeconomic status can provide more resources to stimulate students' motivation for exploration (Spinath, 2012). Gender and grade-level differences vary due to cultural and educational experiences (Fuchs & Fuchs, 2006). This study utilizes PISA 2022 data to investigate the relationship between the curiosity classes and the mathematical literacy (ML) of 15-year-old students in Taiwan. Through latent class analysis (LCA), the study examines the characteristics of different latent groups and their mathematics performance, further exploring the impact of socioeconomic status, gender, and grade level on ML.

Research Purpose

This study explores the relationship between the curiosity and ML of 15-year-old Taiwanese students participating in PISA 2022. The specific research objectives include: 1. Examining students' response patterns related to curiosity; 2. Analyzing the latent classes of curiosity; 3. Investigating the relationship between gender and the latent classes of curiosity; 4. Analyzing the differences in ML across different latent classes of curiosity; 5. Examining the moderating effects of mathematical literacy, socioeconomic status (SES), gender, and grade level among latent curiosity classes.

Research Methods

To achieve the research purpose, SPSS was used to perform descriptive statistical analysis to present the relationship between curiosity scale scores and ML. LCA was conducted using Mplus software to categorize students' curiosity into latent classes and to evaluate model fit indices. This study coded "Strongly Agree" and "Agree" as 2, "Neutral" as 1, and "Strongly Disagree" and "Disagree" as 0 for latent class model analysis. Subsequently, the BCH method was used to analyze the distribution differences of gender across different latent classes and their MLs. The moderating effects of SES, gender, and grade level within different latent classes were also examined. Finally, a comprehensive analysis was conducted using the ten ML indicators provided by PISA, and the results were discussed based on the averages.

Research Results

The LCA analysis results show that the curiosity of Taiwanese students in PISA 2022 can be divided into four potential categories. The category names and percentages are: "High Curiosity" group (38%), "Moderate Curiosity" group (36%), "Low Curiosity" " group (11%), and the "No Comments" group (14%).Among these classes, "High Curiosity" students demonstrated the highest ML, with an average score of 573.4, followed by the "Moderate Curiosity" group (553.4), the "Low Curiosity" group (529.5), and the "No Comments" group was the lowest (480).

There are 31% girls and 43% boys in the "High Curiosity" group. Taking the "High Curiosity" group as the reference group, the odds ratios of the "Moderate Curiosity" group and the low curiosity group were .542 and .528 respectively, both reaching statistically significant levels, showing that the proportion of boys in the high curiosity group was higher, while that of girls' proportions of "Moderate Curiosity" and "Low Curiosity" are significantly higher than those of boys. In the "No Comments" group, the gender ratio was about the same.

Regarding the gender difference in ML, the ML of all boys is 6.2 points higher than that of girls, which is not a significant difference. However, when incorporating potential curiosity classes, it was found that for students in the "High Curiosity" group and "No Comments" group, boys were 0.8 and 2 points higher than girls respectively, both of which were not significant; in the "Moderate Curiosity" group, Boys scored significantly higher than girls by 17.1 points; on the contrary, in the "Low Curiosity" group, boys scored about 14 points lower than girls.

Much research literature has confirmed the relationship between SES and academic performance. In this study, each one-unit increase in SES corresponds to 49.6 points in students' ML. However, when incorporating latent curiosity classes, it was found that for "Low Curiosity" students, each one-unit increase in SES corresponds to an increase of approximately 61 points. For "Moderate Curiosity" students, the increase is only around 37 points, while for "High Curiosity" students, the benefit is approximately 50 points. From the perspective of grade effect, only the "High Curiosity" group is significant, but the tenth grade score is significantly lower than that of the ninth grade by 27 points, which deserves further study in the future.

Conclusion

The LCA analysis from PISA 2022 categorizes Taiwanese students' curiosity into four groups, revealing a strong correlation between curiosity levels and academic performance. High curiosity students achieve the best results, while gender distribution varies, with more boys in the high curiosity group and more girls in moderate and low curiosity groups. Additionally, socioeconomic status significantly impacts learning outcomes, with higher status correlating with better performance, particularly among low curiosity students. These findings highlight the need for further investigation into the interplay of curiosity, gender, and socioeconomic factors, encouraging educators to develop targeted strategies to enhance student engagement and achievement.

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PP1-13

THE RELATIONSHIP OF STRESS RESISTANCE AND MATHEMATICAL LITERACY: A LATENT CLASS ANALYSIS

Pi-Ying Li
National University of Tainan, Taiwan, swhite.bee@gmail.com

Su-Wei Lin
National University of Tainan, Taiwan, swlin0214@mail.nutn.edu.tw

Keywords: PISA ; STRESS RESISTANCE ; MATHEMATICAL LITERACY ; GENDER DIFFERENCES

Background Introduction

Adolescents face multifaceted pressures, including academic, familial, emotional, and peer-related challenges. These pressures are related to mental health issues and academic performance. Many important education guidelines emphasize the development of students' core competencies, particularly in emotional regulation and stress resilience (e.g. OECD, 2019). In Taiwan, with the long-standing pressure of entrance exams for higher education, students often experience stress and anxiety in mathematics learning (Mohamed & Tarmizi, 2010). In addition, there are significant gender differences in mathematics (e.g. Danan & Ashkenazi, 2022).

Research Objectives

This study investigates the relationship between stress resilience and mathematics performance. By adopting latent class analysis to explore the latent categories of students' stress resilience, and further examine the mathematical literacy among different stress resilience categories and the gender differences in mathematical literacy under different stress resistance categories.

Research Methodology

This study uses data from PISA 2022, which the OECD conducted. The Taiwan sample size is 5,772, and the total number after weighted back to the population is 190,657. Core variables in this study are students' responses to the stress resilience scale and mathematical literacy, which were the ten plausible values (PVs) calibrated by OECD. Gender is a background variable.

This study uses SPSS and Mplus to analyze research data. The analysis steps included: (1) Data cleaning with SPSS, recoding stress resilience responses on a scale from 0 (low resilience) to 2 (high resilience); (2) Latent Class Analysis (LCA) with Mplus to classify stress resilience states, using AIC, BIC, and aBIC along with the Elbow Point method to determine the optimal number of classes; (3) Use MLR (Maximum Likelihood Robust) estimation to deal with missing data; (4) Use the BCH method to control the classification error, and then to explore the relationship between mathematics literacy and stress resilience; and gender differences on mathematical literacy.

Research Findings

Taiwan's students were classified into four stress resistance categories based on their stress perceptions and adjustment abilities: "high stress, low adjustment," "low stress, high adjustment," "high stress, high adjustment," and "no response" (Table 1). The "high stress, low adjustment" category had the largest proportion (34.95%), followed by "high stress, high adjustment" (26.51%), "no response" (20.77%), and "low stress, high adjustment" (17.78%). Students in the "low stress, high adjustment" group have the highest mathematical literacy, while students in the "no response" group have the lowest.

Regarding the association of gender and stress resistance categories, the results are shown in Table 2; this study used the "no response" as the reference group, and the odds ratios for males compared to females were: "low stress, high adjustment" 0.969, "high stress, high adjustment" 0.853, and "high stress, low adjustment" 0.361. All odds ratios were below 1, suggesting males were less likely to fall into these categories. However, these results were not statistically significant, indicating a limited effect of the association of gender and stress resistance categories.

Table 3 presents the gender differences in mathematical literacy in different stress resistance categories. The results show that gender differences in mathematical literacy varied across categories. Students in the "low stress, high adjustment" category had the highest mathematical literacy, with females outperforming males by 14.54 points, but the difference is not statistically significant. The "high stress, low adjustment" category showed the largest gender difference, with males significantly outperforming females by 25.696 points. In the other categories, gender differences existed but were not significant. It suggests that gender differences in mathematical literacy are different under different stress resistance categories.

Table 1. Mathematics Literacy in the Four Stress Resistance Categories.

	High stress, low adjustment	Low stress, high adjustment	High stress, high adjustment	No response
Mean	561.478	562.534	557.124	498.263
Standard deviation	99.537	116.487	114.799	105.243
Category size (%)	34.95%	17.78%	26.51%	20.77%

Table 2. Odds Ratios of Gender across Different Stress Resistance Categories

	High stress, low adj.	Low stress, high adj.	High stress, high adj.	No response	Total
Female proportion	14.7%	24.6%	45.5%	15.2%	100.0%
Male proportion	21.3%	31.3%	24.6%	22.8%	100.0%
Odds ratio	0.969	0.853	0.361	1	

Table 3. Gender Differences in Mathematical literacy in Different Stress Resistance Categories

	High stress, low adj.	Low stress, high adj.	High stress, high adj.	No response	Overall
Female	552.145	571.319	547.696	494.754	545.122
Male	577.841	556.779	564.134	500.495	551.431
Difference (male-female)	25.696	-14.540	16.438	5.741	6.309

Conclusion

This study confirms a strong correlation between stress resilience and mathematical literacy, with low-stress, high-adjustment students achieving the highest scores. Significant gender disparities in mathematical literacy emerged, particularly among high-stress, low-adjustment students where males outperformed females. It suggests that stress resilience profoundly impacts mathematical achievement, while the gender-performance link is complex and contingent on individual coping mechanisms. Recommendations include enhancing students' stress management skills, particularly for high-stress/low-adjustment students, and developing gender-sensitive teaching strategies. Further research using longitudinal studies and interdisciplinary collaboration is needed to fully understand the dynamic relationship between stress, gender, and mathematical literacy, paving the way for personalized instruction that optimizes learning outcomes.

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PP1-14

SUPPORTING LOCALIZED AND CONTEXTUALIZED LEARNING IN BASIC CALCULUS USING BILINGUAL MODULES: A PRELIMINARY INVESTIGATION

Jake B. Garnace

University of Northern Philippines, Philippines, jake.garnace@unp.edu.ph

Eduard M. Albay

Don Mariano Marcos Memorial State University, Philippines, ealbay@dmmmsu.edu.ph

Introduction

Magsino (2018) argued that Basic Calculus is a difficult subject for the students, as it requires a strong foundation in Algebra. Concerning this, Sahin, et al (2015) affirmed that the concept of derivatives in calculus is difficult for students. Nasir, et al (2013) concluded in their study that solving differentiation problems is difficult for students while Yushau and Hafidz-Omar (2015) found out that the students' proficiency level in English is a factor in their Mathematics understanding and performance. Semingson, et al (2015) argued that the development of bilingual books can serve as a support in developing the abilities of the learners in using the two languages. Reading bilingual books may be a useful tool for vocabulary learning (Zhang and Webb, 2019) and bilingual education serves as a bridge building connection between two languages (Ozifdan, 2014). Studies have proven that instructional materials promote better learning outcomes across different disciplines. Instructional materials help learners perform better and higher as compared to those taught without IM (Adalikwu & Iorkpilgh, 2013; Okori a& Jerry, 2019) With these premises, this study aimed to determine how bilingual modules support localized and contextualized learning in basic calculus using bilingual modules.

Theoretical Bases

The following theories and methodologies collectively formed the foundation in localizing and contextualizing the Bilingual Modules in Derivatives. The Threshold Hypothesis (Cummins, 1976), Vygotsky's (1978) Theory of Scaffolding and the Zone of Proximal Development (ZPD), Gardner's Theory of Multiple Intelligences, Inquiry-Based Learning (IBL), Experiential Learning, Collaborative Learning promotes group activities for shared problem-solving, Reflective Learning and the constructivist approach.

Methodology

This research employed the research and development methodology and the true experimental posttest-only control group design involving the experimental group (who used the Bilingual Modules) and the control group (who used the English Modules). The three phases of the study comprised the development and validation of the module, experimentation or tryout of the developed modules, and the conduct of the posttest. The performance of the students was measured using a 60-item multiple choice test, and data were analyzed using the Mann-Whitney U Test.

Results

Validity of the Bilingual Modules

As shown in Table 1, validators noted passing score on the four factors, noting that the developed Bilingual Module does not have ideological, cultural, religious, racial, and gender biases and prejudices, provide learning activities that require higher-order thinking skills and assumes users with increased responsibility in learning. Moreover, the module was found to be well-formatted with quality materials and binding, is accurate, clearly organized, and up-to-date, which supports active engagement and better understanding.

Table 1. Summary of the Ratings of the Developed Bilingual Modules

Factors	Rating	Remarks
Factor 1: Content	26.20	Passed
Factor 2: Format	63.00	Passed
Factor 3: Presentation and Organization	19.20	Passed
Factor 4: Accuracy and Up-to-datedness of Information	24.00	Passed

As reflected in Table 2, the performances of the two groups are not statistically significant (p-value=0.847), and therefore, the levels of performance of the learners exposed to English modules and Bilingual Modules are comparable. However, the higher mean score of the participants in the experimental group reflects evidence that the use of Bilingual Modules in teaching Basic Calculus has provided them with an effective method of learning relevant concepts and skills in differentiating functions. Results conform with Abdullah's (2016) findings that learners using both Urdu and English languages in the delivery of instruction leads to significantly higher performance compared to using English alone.

Table 2. Comparative Level of Performance of the Experimental and Control Groups using the Mann-Whitney U Test

Groups	Mean Score	Level of Performance	Mann-Whitney U Test Statistic	p-value
Control Group	42.13	Very Good	437.000	0.847
Experimental Group	42.97	Very Good		

Conclusion

Results reveal that localizing and contextualizing books and modules using bilingualism can serve as a support in developing the abilities of the learners in using two languages while learning the Basic Calculus (Semingson, et al ,2015; Pfefferle and Waitz, 2015; Ohlberger and Wegner, 2017; and

Zhang and Webb (2019). Future studies could include other factors that affect the learning calculus like study habits and attitudes towards Mathematics, and could test whether the utilization of bilingual modules on other topics in mathematics yields with similar results.

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PP1-15

STUDENT EXPERIENCES AND BARRIERS IN MATHEMATICAL CREATIVITY

Yujin Lee
Kangwon National University, Korea, ylee@kangwon.ac.kr

Ali Bicer
Texas A&M University, USA, alibicer@tamu.edu

Introduction

Research suggests that students do not experience equal opportunities to engage in creative mathematical thinking due to differences in instruction, assessment structures, and classroom expectations (Kozlowski & Si, 2019). Many students, particularly those in under-resourced schools or those perceived as struggling in mathematics, receive instruction that prioritizes rote learning over exploration, procedural fluency over reasoning, and correctness over creativity (Boaler, 2016). This study explores how individual students experience mathematical creativity (MC) within their learning environments and whether they feel equally encouraged to engage in creative problem-solving. MC is defined as the ability to generate mathematical ideas that are new to the creator but may not necessarily be new to others (Bicer, 2021). Research suggests that students' opportunities to develop MC are influenced by classroom norms, teacher expectations, and school structures (Luria et al., 2017). Equity in mathematics education is not merely about providing all students with the same resources; rather, it ensures that all students, particularly those from historically marginalized backgrounds, have the support and instructional approaches necessary to engage meaningfully with mathematical concepts (Gutiérrez, 2008). Prior research suggests that students from different backgrounds experience creativity differently in math classrooms, with some being encouraged to explore and take risks, while others are expected to conform to rigid, procedural learning structures (Luria et al., 2017). This study seeks to understand these differences by focusing on individual students' experiences with MC.

Research Questions

Research questions of the current study are as below.

1) How do individual students experience and engage with MC in their classrooms?
2) What barriers do students face in accessing creative problem-solving or -posing opportunities in mathematics?
3) How do students' prior learning experiences shape their confidence and participation in creative mathematical thinking?

Methodology

This qualitative study examines five students from different grade levels (3rd, 4th, 6th, 7th, and

9th), focusing on their individual experiences. Participant will complete grade-appropriate multiple solution tasks designed to assess fluency, flexibility, and originality (Leikin & Pitta-Pantazi, 2013). To capture students' perspectives on MC and equity in mathematics, data will be collected through task-based observations, interviews, and student reflections. Rather than drawing generalizations across grade levels, this study focuses on understanding individual experiences to explore how different students encounter and engage with MC.

Expected Contribution

This study will contribute to: 1) identifying potential barriers that limit students' ability to engage in creative problem-solving, 2) highlighting how classroom environments shape students' confidence and willingness to engage in creative mathematical thinking, including differences in teacher expectations, peer dynamics, and instructional practices, 3) providing recommendations for educators on how to design creativity-driven, equity-focused instruction that supports all students, ensuring that creative engagement in mathematics is not reserved for high-achieving or privileged students (Luria & Kaufman, 2017).

Conclusion

By bridging mathematical creativity with equity, this study challenges the dominant narrative that mathematics is solely about procedural correctness. Research has demonstrated that creativity can serve as an equalizing force in mathematics education by allowing students to engage in problem-solving in ways that reflect their strengths, perspectives, and lived experiences (Kozlowski & Si, 2019). If creativity fosters deeper understanding, confidence, and long-term engagement in mathematics, then ensuring that all students—regardless of their background or prior achievement—have access to creativity-driven instruction is not just a pedagogical choice but a matter of educational justice.

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PP1-16

STUDENTS' CONCEPTION OF LEARNING DURING PROGRAMMING-RICH MATHEMATICAL ACTIVITIES

Oi-Lam Ng
The Chinese University of Hong Kong, Hong Kong SAR, oilamn@cuhk.edu.hk

Athena Chan
St. Antonius Girls' College, Hong Kong SAR, athenachan59@yahoo.com.hk

Max Stephens
University of Melbourne, Australia, m.stephens@unimelb.edu.au

Introduction

The paper highlights computational thinking (CT) as an essential skill for problem-solving and digital literacy. Despite efforts of local curriculum changes to emphasize CT and programming skills, significant gaps in digital literacy persist, particularly among disadvantaged communities in Hong Kong (Reichert et al., 2020). In response, the current Knowledge Transfer Project designed to improve programming and mathematical skills through community engagement, aiming to foster equitable digital literacy. The project aims to empower teachers and students by integrating CT into mathematics education through partnerships with schools and community organizations. It is informed by the first author's previous research findings which envisioned a "computationally enhanced mathematics education" (Ng & Cui, 2021) by incorporating block-based programming into mathematics instruction. Project activities include a free course titled "I'm a Programming Mathematician," professional development workshops for local teachers, and practicum experience for pre-service teachers. Since January 2024, the said project has collaborated with five schools and one nonprofit organization, reaching over 100 students, especially in underprivileged areas.

CT as a Boundary Process in Programming-rich Mathematical Activities

The project incorporates programming-rich activities that connect mathematics and computer programming learning outcomes using Scratch. We draw on the work of Ng et al. (2023), which conceptualizes CT as a "boundary process" bridging the domains or disciplines of mathematics and computer programming. For example, CT concepts such as variables, abstraction, pattern recognition, and subroutines act as bridges between mathematics and programming. This approach recognizes CT as mediating across STEM communities, allowing learners to connect across mathematical concepts and programming practices, co-constructing disciplinary knowledge and skills.

Method of Evaluation and Findings

We evaluate the project's impact on students' conception of learning through interviews conducted with eight students from two primary schools served. Students were asked to draw pictures reflecting and then discussing their learning experiences in programming and traditional mathematics classes. Analysis focused on themes such as engagement, empowerment, and skill development.

1. **Student Agency and Active Learning:** Programming classes encouraged self-directed exploration, contrasting with teacher-centered mathematics lessons. Students described programming as enjoyable and empowering, while mathematics classes as monotonous.
2. **Open-Ended Learning**: Scratch programming tasks allowed multiple solutions, fostering creativity and discovery. Conversely, mathematics lessons emphasized single correct answers, discouraging exploration.
3. **Personalized Learning**: Students appreciated the tangible outcomes of programming projects, which often carried personal significance. In contrast, mathematics tasks were viewed as abstract and disconnected from real-world applications.
4. **Collaborative Learning**: Programming classes fostered a sense of community through project sharing, unlike traditional mathematics classes, which lacked interactivity.
5. **Role of Teachers**: Programming teachers acted as facilitators, emphasizing discovery and exploration, whereas mathematics teachers followed rigid, authoritative teaching methods.

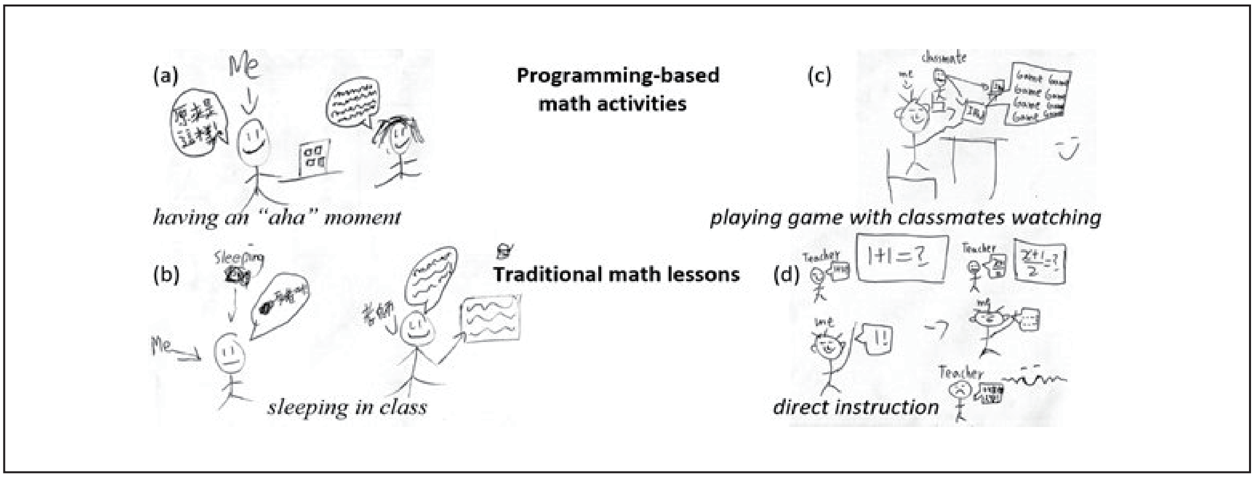

Figure 1. Two students' conception of learning in (a, c) programming-based math activities and in (b, d) traditional math lessons as expressed in their drawings

Conclusion

The study demonstrates the potential of integrating CT into mathematics education to empower students in underprivileged communities: (1) Students find programming activities more engaging and view them as a form of "play," which enhances intrinsic motivation; (2) the activities empowered students to take ownership of their learning by creating personalized projects, fostering a sense of accomplishment and agency; (3) by bridging mathematics and programming, CT equips students with transferable problem-solving skills that are essential for success in a digital world. The findings underscore the need for curricular reforms and pedagogical shifts toward incorporating programming-rich mathematical activities (Broley et al., 2024).

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PP1-17

A SYSTEMATIC LITERATURE REVIEW OF THE EMPIRICAL STUDIES ON STEAM EDUCATION IN KOREA: 2011-2019

Kyeongjun Kim
Seoul National University, Korea, rudwnsl91@snu.ac.kr

Kyungwon Lee
Seoul National University, Korea, kyungwon.lee.snu@gmail.com

Oh Nam Kwon
Seoul National University, Korea, onkwon@snu.ac.kr

This study, derived from Kim et al. (2024), aims to illustrate the Korean perspective on the implementation of STEAM education through a systematic literature review of domestic empirical studies conducted between 2011 and 2019. Using RISS (Research Information Sharing Service), the representative research search engine for research papers in Korea, a total of 794 research reports were identified using the search terms 'STEAM education', 'STEAM program', 'STEAM-based learning', and 'STEAM human resources.' Among these 794 research reports, academic journal articles with an impact factor of the KCI (Korean Citation Index) greater than 0.7 were selected, excluding conference proceedings and dissertations, resulting in 330 studies. Titles, abstracts, and keywords of the 330 studies were reviewed, and non-empirical studies were excluded. Finally, after assessing the eligibility, a systematic literature review was conducted on 186 studies. The systematic literature review based on 186 domestic empirical studies focused on trends over time, school levels, research methods, participants, sample sizes, and levels of integration. First, the number of the empirical studies on STEAM education in Korea from 2011 to 2019 has been steadily increasing. In 2014 and 2015, 32 studies were conducted in each of those years. Although the number of research publications began to decline after 2015, studies on STEAM education had been conducted steadily until 2019. The number of empirical studies on STEAM education in Korea is connected to the introduction of the educational policy on STEAM education. Second, empirical studies on STEAM education in Korea were concentrated at the K-9 level. 90 studies were conducted at the elementary school level, which can be attributed to the autonomy given to Korean elementary school teachers in organizing subjects. Third, empirical studies on STEAM education in Korea mainly adopted quantitative research methods. These studies primarily target students with relatively small sample sizes ranging from 1 to 50. Fourth, research on teaching and learning in STEAM education and participants' perceptions generally takes multidisciplinary approaches rather than interdisciplinary or transdisciplinary approaches. The results of this study can be applied to designing future STEAM education research and the teaching and learning of STEAM education.

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PP1-18

DEVELOPMENT AND APPLICATION OF AI MATHEMATICS DIGITAL TEXTBOOKS: FOCUSING ON THE KOREAN CASE

Mangoo Park
Seoul National University of Education, Korea, mpark29@snue.ac.kr

The development and application of AI digital textbooks have gained significant attention in mathematics education. Various developed countries have integrated AI into digital textbooks to personalize learning, provide real-time feedback, and enhance engagement. This study explores the development and application of AI mathematics digital textbooks worldwide, focusing on Korea's unique approach. Through a literature review, the researcher analyzes the advantages, limitations, and future considerations of AI-driven digital textbooks based on the Korean case. The findings suggest that AI digital textbooks can revolutionize mathematics education by adapting to individual learners' needs while also presenting challenges such as data privacy and accessibility.

Keywords: mathematics education, digital textbook, functions, applications, Korean

Introduction

The integration of artificial intelligence (AI) in digital textbooks has emerged as a crucial development in mathematics education. Traditional textbooks often fail to meet the diverse needs of students, whereas AI digital textbooks can provide personalized learning experiences, real-time assessment, and adaptive feedback (Korea Education and Research Information Service, 2023; Luckin et al., 2021). The importance of AI in digital textbooks is supported by research demonstrating improvements in student engagement and learning outcomes (Zawacki-Richter et al., 2019).

Several countries have actively developed AI digital textbooks. For instance, the United States has introduced AI-powered platforms such as Carnegie Learning, which tailors content based on student responses. In Japan, including GIGA school, AI digital textbooks are prepared for adaptive learning algorithms to support individualized instruction. China, with platforms like Squirrel AI, has also implemented AI-driven mathematics platforms that use big data analytics to track and optimize student progress (Huang & Yang, 2022).

This study aims to examine the development and application of AI mathematics digital textbooks with a particular focus on Korea's approach. By analyzing global trends and Korea's unique contributions, this research seeks to provide insights into the future of AI-driven mathematics education.

Development and Application of AI Digital Textbooks

Research on AI-based digital textbooks has expanded in recent years, with studies highlighting their potential to enhance learning. In the United States, AI-powered mathematics textbooks utilize machine learning algorithms to identify students' strengths and weaknesses, allowing for customized content delivery (Baker & Smith, 2020). Similarly, European countries like Finland have integrated AI-driven digital platforms into their curricula to support self-paced learning (Salminen et al., 2021).

Advantages of AI Mathematics Digital Textbooks

1. Personalized Learning: AI adapts content based on students' progress, ensuring a tailored educational experience.
2. Real-time Feedback: Immediate assessment and corrective feedback enhance learning efficiency.
3. Engagement and Motivation: Interactive AI features promote student interest and engagement.
4. Data-Driven Insights: Teachers gain valuable analytics on student performance for informed instruction.

Limitations of AI Mathematics Digital Textbooks

1. Data Privacy Concerns: The collection of student learning data raises ethical and security issues.
2. Accessibility Challenges: Not all students have equal access to AI-driven resources.
3. Dependence on Technology: Over-reliance on AI tools may reduce fundamental problem-solving skills.

Korea's AI Mathematics Digital Textbook Development

Korea has introduced AI digital textbooks as part of its national educational initiative. The Korean AI digital mathematics textbooks emphasize adaptive learning, automated assessments, and integration with online learning platforms. Unlike Western models, Korea's system is closely aligned with the national curriculum, ensuring consistency in educational standards (Kim & Lee, 2023).

In Korea, AI digital textbooks are defined as "software equipped with various learning materials and learning support functions using intelligent information technology including artificial intelligence to support various customized learning opportunities that are suitable for each student's ability and level" (p. 12).

When developing AI digital textbooks, the Korea Education and Research Information Service (2023) presented the following guidelines on principles and directions under the catchphrase "5 million textbooks for 5 million students" (pp. 15-16).

It suggests three development principles as follows.

- Education for human dignity: Education authorities, professional organizations, and private organizations participating in development understand the impact of AI technology on individuals and society, and plan education for children's lives.
- Guaranteeing equal learning opportunities: Designing so that children can access new technologies and have customized education opportunities regardless of their social, cultural, and economic backgrounds such as language, disability, region, and class.

- Respecting teachers' expertise: Assuming that all children have abilities beyond what can be measured by new technologies, AI supports teachers' activities such as class preparation and evaluation records so that teachers can observe and support this.

It suggests three development directions as follows.

- Based on the revised 2022 curriculum, it should be designed to provide supplementary learning (for slow learners) and in-depth learning (for advanced learners) based on the learning analysis results.
- Design functions and UI/UX so that all users can use it easily and conveniently, aiming at realizing customized education for everyone.
- Provide a foundation for continuous improvement of the education system through learning analysis at the user, school, and national levels so that educational stakeholders such as students, teachers, parents, and policymakers can make data-based decisions about learning.

Method

This study adopts a literature review approach, analyzing research published since 2020 on AI digital textbooks. The methodology includes:

- Keyword Search: Reviewing academic databases for "AI digital textbooks" and "mathematics education."
- Comparative Analysis: Extracting and comparing key studies from leading countries in AI digital textbook development.
- Case Study of Korea: Examining the process and characteristics of Korea's AI mathematics digital textbooks.

Conclusion

The development and application of AI digital textbooks are rapidly advancing, with numerous countries leveraging AI to enhance mathematics education. AI textbooks offer significant benefits, including personalized learning, real-time feedback, and data-driven insights. However, challenges such as data privacy, accessibility, and technological dependence must be addressed.

In the future, AI mathematics digital textbooks should incorporate:

- Ethical AI usage to ensure student data privacy.
- Equitable access to technology to prevent educational disparities.
- Hybrid learning models that balance AI-driven and traditional instructional methods.

The continued refinement of AI digital textbooks will shape the future of mathematics education, ensuring that learners receive high-quality, individualized instruction.

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PP1-19

PROPORTIONAL REASONING IN THE THIRD GRADES OF ELEMENTARY SCHOOL: FOCUSING ON THE COMPOSED UNIT

Hisae Kato
Hyogo University of Teacher Education, Japan, katohi@hyogo-u.ac.jp

Ai Terai
Matsue Elementary School, Japan, manmaruaichan@gmail.com

Yumi Ueno
Gion Elementary School, Japan, me185503@uu-pt.net

Keiko Hino
Utsunomiya University, Japan, khino@cc.utsunomiya-u.ac.jp

Hiraku Ichikawa
Miyagi University of Education, Japan, hiraku-i@staff.miyakyo-u.ac.jp

Background and Purpose of This Study

Most research on proportional reasoning in mathematics education has focused on junior high school students and older elementary school students. In this study, we have proposed a learning trajectory for proportional reasoning based on the results of a survey of children and classroom practice, and we have developed mathematics lessons that foster proportional reasoning in younger children while using this learning trajectory as a tool to examine the learning process (e.g., Hino et al., 2021). The learning trajectory is based on two types of ratios: scalar ratios (SR) and functional rates (FR; Vergnaud, 1994). In this presentation, we focus on the learning trajectory of scalar ratios (SR). SR is a ratio (scalar) in which when one quantity that is proportionally co-variant with another quantity is multiplied by n, the other quantity is also multiplied by n. With the aim of promoting children's use of SR, we designed and implemented two lessons in which children developed two methods of adjusting quantities using 'composed units' (Lobato et al., 2010, p.19). According to Vanluydt et al. (2020), research on the progress of children's ability to handle composed units from 5 to 9 years old has revealed that there is a large individual difference in the progress of their ability to solve proportional reasoning problems from one-to-many to many-to-many correspondence problems. In this presentation, we conducted a class using problems involving 1 in proportional reasoning with many-to-many correspondence with third-grade students (aged 8-9) in Japan. The aim of this presentation is to examine the aspects of the SR specifications of children by analyzing how children use 1 in those classes through the analysis of the diagrams drawn by the children.

Lesson Study 1: Finding 'How Many Times'

Problem 1: Four strawberries and six chocolates are put on one pack of roll cake. Four packs of roll cake are made. How many strawberries and chocolates are needed respectively?

This lesson dealt with Problem 1. The children were able to immediately answer the formula 4×4=16 and 6×4=24. After that, they were asked to draw a diagram to show that the formula was correct. Some children drew a roll cake with two quantities of strawberries and chocolate corresponding to it, but others drew separately a roll cake with a quantity of strawberries corresponding to it (one-to-many) and a quantity of chocolate corresponding to it (one-to-many) (Figure 1). In this way, it was observed that some children were able to recognize one-to-many relationships. However, we are not sure if this recognition of one-to-many relationships could extend to the recognition of many-to-many relationship between the number of strawberries and the number of chocolates.

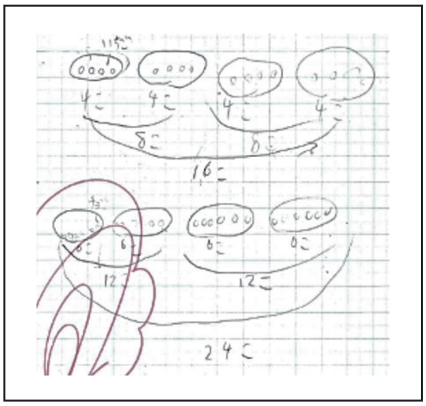

Figure 1. One-to-many correspondence by a child

Lesson Study 2: Division with Remainder

Problem 2: We make a toy car by using four tires and two boxes. There are 30 tires. In order to make cars as many as possible, how many boxes do we need, and how many cars can we make?

The second lesson dealt with Problem 2. In this lesson, some children only focused on one quantity, while others solved the problem using multiplication to match up the two quantities. In one case, a child counted the number of cars as '1' when combining four tires and two boxes (Figure 2). This child's approach can be considered an example of the effective use of the number '1' because from the representation of "1," "2," … "7" around the circles, we can assume that the child is counting the number of composed units (probably the number of cars).

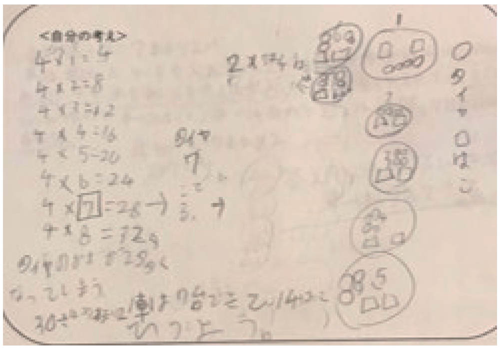

Figure 2. Many-to-many correspondence using 1 by a child

Conclusion

In the two lessons introduced in this presentation, the children dealt with problem situations involving three quantities in total, adding a quantity that represents 1 to the many-to-many relationship. The results of analyzing the illustrative representations drawn by the children showed that there was a variety of ways of using '1'. The child shown in Figure 1 did not express the correspondence between the two quantities of many-to-many and solved the problem by using two types of one-to-many. The child shown in Figure 2 expressed the composed unit of the two quantities of many-to-many, and it is thought that the child used '1' by counting the number of composed units. We would like to report on the details of the drawings made by other children in a poster. In our poster, we would like to identify the SR stage of children by analyzing these illustrative representations and gain insights into examining their learning trajectories in detail.

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PP1-20

CONSTRUCTION OF THE LEARNING PROCESS OF GRAPH THEORY IN SCHOOL MATHEMATICS: THE EVOLUTION OF THE REPRESENTATION WORLD OF GRAPH

Yuki Tanimoto

Graduate School of Comprehensive Human Sciences, University of Tsukuba, Japan,
yuuki635314@gmail.com

Keywords: graph theory, level of reasoning, representation world

Introduction

Graph theory is an important area of discrete mathematics that should be included in the mathematics curriculum in schools. A "graph" in this context is an abstract concept referring to a finite number of elements and the relationships among them. A "graph" can be represented diagrammatically using points and lines.

Learning graph theory presents certain challenges. In particular, understanding the relationships between different representation systems that lack visual resemblance requires a shift from the basic levels of reasoning to an upper level often difficult to achieve without instruction (González et al., 2021). Students often struggle to relate diagrammatic graph representations to real-world situations in which the diagrammatic representations of graphs are not naturally produced, that is, in which the phenomena corresponding to the vertices and edges of a graph are not self-evident. Overcoming this challenge is crucial for developing the ability to find discrete structures in today's data-driven world, mathematize them using graph representations, and solve the problems mathematically.

Although previous research has focused on the development of teaching materials and classroom practices for graph theory, there is a need for discussion on the learning process to overcome this difficulty. The purpose of this study is to construct a learning process that helps students bridge the gap between diagrammatic representations and real-world situations, particularly in which the phenomena corresponding to the graph's vertices and edges are not immediately clear.

Method

This study establishes learning goals based on the characterizing levels of reasoning in graph theory developed by González et al. (2021). Isoda (2015) extended Freudenthal's original framework for designing curriculum by applying Isoda's representation theory and introduced the "construction principle of mathematization process" (p. 314). Based on this principle, this study constructs the learning process of graph theory, designed to help students achieve these goals.

Construction of the learning process of graph theory

The goals for overcoming the aforementioned difficulty are shown in Table 1.

Table 1. Goals for connecting graph diagrams to real-world situations

Level of Reasoning	Learning goals
Level 1	Visualize real-world phenomena in a particular (not necessarily diagrammatic) graph representation, focusing on their general shape.
Level 2	Translate a graph representation into a different, not necessarily visually similar, representation by changing the use of symbols.
Level 3	Analyze the properties of the translated representation in relation to the original representation.

Isoda (2015) suggests that a learning process based on the "construction principle of mathematization process" (p. 314) can effectively guide students through the transition of levels of activity for living by Freudenthal. However, it is necessary to set an existed representation world, an alternative representation world, and an organizing principle. Isoda highlights two key aspects: First, by setting an existed representational world and an alternative representational world and applying the "reconstruction process of the world of representation through mathematization" (p. 144) it is possible to describe the activities to be taken through the transition of levels of reasoning. Second, focusing on a specific organizing principle by Freudenthal in a system of learning contents allows us to construct a learning process tailored to specific content.

Based on these ideas, this study sets existed and alternative representation worlds and the organizing principle as the premises that construct a learning process of graph theory. The existed representation world has a translation rule that converts real-world phenomena into diagrammatic representations of graphs based on a topological view, emphasizing the connections between points, lines, and planes. The alternative representation world has a translation that focuses on elements and their relationships. Furthermore, in this study, the "thought of vertex coloring" is defined as the thought of finding relationships among elements of a set that are in conflict based on certain criteria and dividing the set so that elements in such relationships belong to different groups, rendering it an organizing principle.

The specific learning process, constructed on the aforementioned assumptions, is presented in the poster.

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PP1-21

CULTIVATING ENTREPRENEURSHIP IN PRESERVICE MATHEMATICS TEACHERS: A CASE OF THE INDUSTRY AND MATHEMATICS EDUCATION COURSE

Oh Nam Kwon
Seoul National University, Korea, onkwon@snu.ac.kr

Kyungwon Lee
Seoul National University, Korea, kyungwon.lee.snu@gmail.com

This poster presentation examines the development of entrepreneurship among students majoring in mathematics education through the *Industry and Mathematics Education* course. Entrepreneurship education can foster students' creative and proactive skills (Blenker et al., 2013). Careers for students in mathematics education departments are not limited to becoming teachers, as they may also pursue careers in industrial roles or entrepreneurial pursuits. Entrepreneurship education provides students with a broader perspective on potential careers and encourages the development of innovative teaching methods. This study explores how students' entrepreneurship was cultivated through their experiences by analyzing the curriculum of the *Industry and Mathematics Education* course.

In the fall of 2024, a newly established course titled *Industry and Mathematics Education* was introduced at a university in Seoul, Korea, enrolling five students. The course focused on industry site visits, including visits to four startups, three companies, and one research institute over the semester. These experiences served as the basis for reflective journals that students were required to submit. The authors accompanied students on these site visits and analyzed the development of their entrepreneurship by reviewing their reflective journals. After the course, follow-up interviews were conducted with three of the five students to further explore their experiences and reflections.

The entrepreneurship developed by students can be categorized into three main areas, each closely tied to their potential future roles as educators or entrepreneurs. First, students gained insights into how mathematics and AI are interconnected, enhancing their ability to utilize mathematics as a resource for system design. Visits to three startups and one company provided opportunities to experience applications of AI grounded in mathematical principles. These startups, which focused on services related to mathematics education, helped students understand how mathematics can function not only as disciplinary knowledge but also as a tool for technological development. Second, students explored how creative mathematical thinking and modelling can be transformed into viable business ideas. Through visits to a research institute, a private company, and a startup, they engaged with tasks demonstrating how mathematical thinking and modelling could be leveraged in entrepreneurial contexts. Third, students deepened their understanding of how mathematics can be applied to the development of effective educational curriculum resources. A visit to a textbook publisher enabled them to learn about the overall process of textbook development and to gain an understanding of the structure and objectives of textbook design. These findings illuminate the potential for developing students' entrepreneurship within mathematics education.

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PP1-22

PROPOSAL FOR A THEORETICAL FRAMEWORK TO CAPTURE SPONTANEOUS THOUGHTS WHEN CONSIDERING A CONVERSE PROPOSITION

Takeshi Ando

University of Tsukuba, Graduate School of Comprehensive Human Sciences, Japan,
s2421231@u.tsukuba.ac.jp

Keywords: converse, proposition, statement, proof

Introduction

In the study of proofs, reference is often made to the difficulty in understanding that the converse of a true proposition is not necessarily true. In Japan, proofs are first studied in the second year of junior high school geometry. Although students learn that, while the converse of a true proposition is not necessarily true, a difficulty similar to that mentioned above is encountered, because equivalence theorems and propositions are often studied. While scholars have noted that addressing this difficulty by emphasizing that the converse does not always hold is important (Malek et al., 2017), I also believe that descriptive research that captures the kind of thinking students engage in when thinking about the converse is important. Specifically, I would like to present students with problems in which converse thinking can occur naturally and capture their thoughts. This is because I wish to explore the differences between the thinking of students who consider the converse and those who do not, while I also want to capture both the thinking of students before (or without) they consider the converse as well as while they are considering the converse. To capture these thoughts, a theoretical framework is necessary; however, to the best of my knowledge, no suitable framework has been found. Therefore, this study aimed to design a theoretical framework for capturing thought processes when considering a converse proposition.

Theoretical Framework Development and Discussion

To achieve the objective of this research, it is necessary to select problems in which thinking about the converse naturally occurs and to construct a theoretical framework to capture these problems. Therefore, this study focused on the behavior of thinking about a necessary condition P (i.e., $X \Rightarrow P$) for X or a sufficient condition Q (i.e., $Q \Rightarrow X$) for X when there is a specific thing to be sought (hereafter referred to as X). Hanaki (2011) explains this phenomenon by using discrete graphing materials. Specifically, he considers the task of finding the necessary and sufficient conditions for a shape that can be laid out with dominoes (1×2 tiles). For example, for P, this can be obtained by considering when the dominoes can be laid out (e.g., white squares = black squares when painted in a checkerboard pattern). Conversely, however, the dominoes are not always absolutely laid down ($P \Rightarrow X$ does not necessarily hold). Q can be obtained by considering the cases in which the dominoes can be absolutely laid down (e.g., there exists a Hamiltonian path). However, the fact that the dominoes can be laid down conversely does not necessarily mean that Q holds ($X \Rightarrow Q$ does not necessarily hold). Thus, the natural flow of checking whether the converse is true arises. The goal of the activity carried out by the students is to repeat this process and eventually discover the conditions that are equivalent to X in P and Q. Figure 1 illustrates a Venn diagram representing the set of elements of each state.

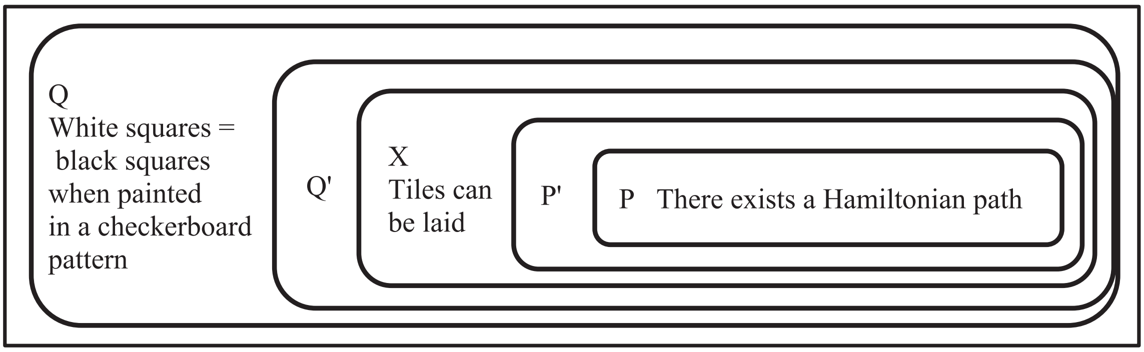

Figure 1. Venn diagram representing the set of elements of each state

With this diagram, I believe that two thoughts can be captured. The first is to increase the number of elements in the set P (to P'). Hanaki called this "weakening the condition of assumption." The second is to reduce the number of elements in set Q (to Q'). Hanaki termed this "strengthening the condition of conclusion. (These ideas are explained in detail in a poster presentation.) The two aforementioned ideas form one of the theoretical frameworks of my study, which will allow me to capture how students narrow or broaden their assumptions or conclusions in response to what they are seeking. In Hanaki's (2011) discrete graphs, Hall's marriage theorem corresponds to X. However, it is difficult for students to derive this theorem. Therefore, I will consider a simpler subject, that is, whether the students will actually conduct the investigation. The specific problems to be investigated will be highlighted in the poster presentation.

Future Issues

First, it is necessary to verify the validity of this framework by conducting an actual survey. Additionally, there is a need to prepare multiple problems and observe both cases in which students think the converse and those in which they do not think the converse to capture the aspect of thinking until they think the converse. Therefore, in the future, it will be necessary to conduct surveys with multiple problems.

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PP1-23

INTERPRETING THE VALUE OF THE TERM "CONSISTENCY" IN CHINA'S NEW MATHEMATICS CURRICULUM STANDARD FOR COMPULSORY EDUCATION

Wenyu Xu
Graduate School of Comprehensive Human Sciences, University of Tsukuba, Japan,
wenyu_xuxu@yeah.net

Keywords: China's Mathematics Curriculum Standards for Compulsory Education, Consistency, Number and Algebra

Introduction

Following the release of the "Mathematics Curriculum Standards for Compulsory Education (2011 Edition)"in 2011, the Chinese Ministry of Education introduced the "Mathematics Curriculum Standards for Compulsory Education (2022 Edition)"(hereinafter referred to as the New Curriculum Standards) in 2022. The New Curriculum Standards introduced the concept of "consistency" for the first time, and in the teaching tips for the domain of "Number and Algebra" in the third learning stage (equivalent to Years 5-6), "Understand that addition and subtraction of integers, fractions and decimals all use the same counting units, and appreciate the consistency of addition and subtraction" (p.26)are elaborated.

Once the teacher receives the new course text, they begin a translation process in order to make adjustments to their existing instruction. The counting units mentioned in the above proposal is the designation that unify the units of place value and fractional units. In the case of the number 234, for example, the counting units for 234 are 100, 10, and 1, and 234 can be represented as $2\times100+3\times10+4\times1$. Therefore, it is not difficult to discern that this recommendation states that teachers should facilitates children to know that whether performing addition or subtraction with integers, decimals, or fractions, the core operation consistently revolves around combining or separating quantities of the same counting units. However, since there is no description of what "consistency" is in the New Curriculum Standards, it is difficult to interpret "appreciate the consistency of addition and subtraction" as the goal of this teaching content. And it presents significant challenges for non-Chinese native speakers in interpreting China's elementary mathematics curriculum framework. This study aims to interpret the meaning of "consistency" as proposed in China's current curriculum reform by systematically reviewing relevant prior research from other countries.

Relevant Prior Research

Kieran's(2018) example of the decomposition of 989 into $9\times100+8\times10+9\times1$is called a place-value decomposition of a number, a structural decomposition. Kieran points out that attention to looking through mathematical objects at the primary and lower middle school levels means developing awareness of the possible and various ways of structuring number and the numerical operations of arithmetic(p.80). As for how to find structure, Sugiyama (2010) points out that once we intuitively recognize what several things have in common, we can find structure by exploring and elucidating the common properties of those things(p.80). Thus, the exploration that addition (subtraction) of integers, decimals, or fractions can all be seen as a process of "addition (subtraction) of the same number of counting units" is also a process of exploring structure. On the other hand, Polya(1954) points out that analogy is a sort of similarity, and "Similar objects agree with each other in some aspect. If you intend to reduce the aspect in which they agree to definite concepts, you regard those similar objects as analogous"(p. 13), and by extension you can make analogies between addition (subtraction) of integers, decimals, and fractions. Furthermore, the exploration of the structural consistency in the addition(subtraction) of integers, decimals, and fractions is accompanied by an analogy between these operations across integers, decimals, and fractions. And it is clear from this passage that the "consistency" mentioned in the New Curriculum Standards corresponds to the "agree with each other" described by Polya. it can be seen that "appreciate the consistency of addition and subtraction" referred in New Curriculum Standards savoring the consistency of the structure of addition (subtraction) of integers, decimals, and fractions. This is consistent with Sugiyama's (2010) view that "if the constructions are found to be the same, the argument of one can be extrapolated by analogy to the other" (p.81).

In comparison, Japan's National Course of Study introduces a concept similar to "counting units," referred to as "units constituting numbers". The National Course of Study(2018) emphasizes that by focusing on the structural representation of numbers and the units constituting numbers, the addition and subtraction of decimals and fractions can be generalized to the addition and subtraction of integers. The National Course of Study demonstrates an intention to promote the integration of addition (subtraction) involving integers, decimals, and fractions among students.

Conclusion

Thus, the description of "consistency" in the New Curriculum Standards presents the intent to promote children's appreciation of the structure of addition(subtraction) of integers, decimals, and fractions. And the teaching of understanding that addition(subtraction) of integers, fractions, and decimals all take place under the same counting units will be key. Regarding the significance of appreciating mathematical structure, Mason(2009) notes that "When procedures are accompanied by even a minimal appreciation of the mathematical structures which make them effective and which provide criteria for appropriateness, learning shifts to focusing on re-construction based on remembering (literally) rather than relying totally on photographic or rote memory"(p.11). The value of the term "consistency" in China's New Curriculum Standards thus lies in shifting the focus of children's learning of addition and subtraction from a focus on algorithms to a focus on structure, enabling the re-construction of learning.

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PP1-24

TASK DESIGN TO ENHANCE MATHEMATICAL LEARNING MOTIVATION THROUGH REALISTIC MATHEMATICS EDUCATION

Pui Yan Wong
The Chinese University of Hong Kong, Hong Kong SAR, franceswpy@link.cuhk.edu.hk

Introduction

In Hong Kong, ethnic minority (EM) students are frequently disadvantaged, facing academic challenges, particularly in mathematics. Research shows that they often struggle to comprehend problems and lack motivation (Elizabeth & Ying, 2020). Globally, mathematics education has often been critiqued for struggling to engage students and connect learning to real-life contexts. Realistic Mathematics Education (RME) addresses this by using real-world scenarios to promote meaningful understanding. In this study, the author designs three RME-based tasks for Secondary 2 (age 13 to 14) EM students in Hong Kong to enhance their motivation in mathematics learning.

Theoretical Framework of Realistic Mathematics Education

Realistic Mathematics Education (RME), introduced by Hans Freudenthal, argues that mathematics should be taught as a human activity relevant to students' lives (Freudenthal, 1973; Gravemeijer, 1994). Freudenthal emphasized engaging students in the practice of mathematics by organizing and transforming real-world situations into mathematical concepts. This approach encourages learners to construct mathematical knowledge through mathematizing real contexts and personal experiences, rather than treating mathematics as a fixed, universally applicable system (Gravemeijer, 1994). Research highlights the effectiveness of RME-based learning activities in shaping students' attitudes toward mathematics. RME not only enhances mathematical success and understanding but also positively influences emotional aspects, such as fostering a more favorable attitude toward the subject (Özkaya & Yetim Karaca, 2017).

Descriptions of Task Design

Task 1: Proof of Pythagoras Theorem

Students cut and paste triangles in squares to explore the proof of Pythagoras' theorem. They can cut out the eight right-angled triangles and then place the triangles in the squares such that the remaining parts were ONE square and TWO squares respectively.

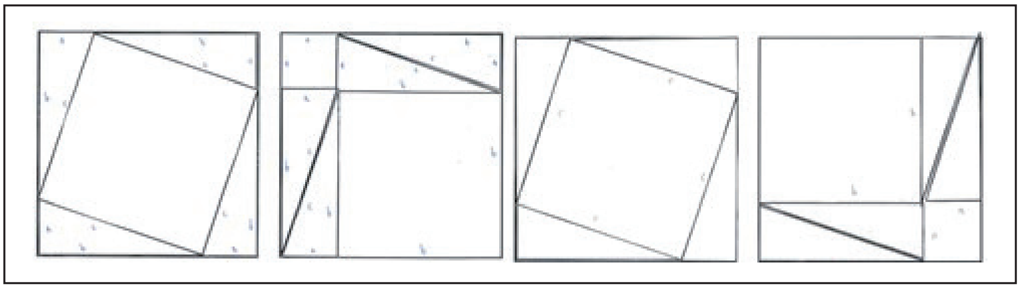

Figure 1. Samples of work of Task 1

Task 2: Exploring the angle sum of polygon

Students are asked to find the angle sum of some polygons. They can try to cut the polygons into several triangles in different ways and try to investigate the relationship between the angle sum and number of sides. Students are then asked to invite a friend in the class to draw a nonagon and a decagon for them. They can creatively design shapes and formulate their own problems to solve.

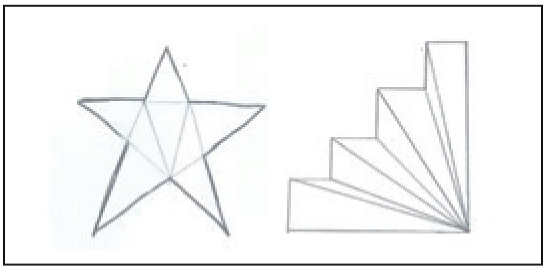

Figure 2. Samples of work of Task 2

Task 3: Application of Trigonometry

Students are asked to estimate the height of a flagpole in the school with a DIY clinometer. They choose their own methods for measurement and calculation, followed by a reflection on potential sources of error.

Discussion of Task Design

In Tasks 1 and 2, students are provided with initial guidance rather than being asked to derive relationships from scratch. This aligns with the RME principle of "guided reinvention" (Freudenthal, 1973), where learners construct their own mathematical knowledge with support, fostering a sense of ownership. The term "realistic" in RME does not require constant use of everyday contexts but emphasizes active knowledge acquisition and problem-solving, enabling intellectual and emotional engagement (Scherer, 2020). In Task 3, following RME principles, students learn mathematics through real-world applications, enhancing relevance and problem-solving skills. Besides, errors and difficulties are addressed meaningfully, allowing students to learn from unsuccessful attempts. Teaching focuses on the process, not just results, encouraging students to share solutions without fear of embarrassment (Cobb, Wood, & Yackel, 1991).

Ingram (2015) emphasizes that learning mathematics should integrate emotions and experiences, with classroom activities fostering engagement, creating meaningful moments, and making mathematics relevant. Hands-on activities transform students' experiences and emotions, influenced by their anticipation of achievement and progress (Ingram, 2015). These emotions shape their willingness to engage, their relationship with mathematics, and their attitudes toward it. Intrinsic motivation arises from a sense of achievement and autonomy, supported by the value-expectancy model (Wigfield & Eccles, 2000), which highlights the importance of valuing learning and having positive achievement expectations. The activities foster accomplishment by showcasing progress and revealing the significance of mathematical concepts, positively reshaping students' feelings toward mathematics.

Conclusion

RME emphasizes relational and conceptual understanding over rote learning, offering students meaningful mathematical experiences through well-designed tasks (Barnes, 2005). By integrating realistic tasks, mathematics education fosters deeper understanding and a positive learning environment, empowering students to explore and engage with mathematical concepts. RME enables a more inclusive and relevant curriculum, preparing students for real-life challenges. Future research should investigate the design of a range of RME-based tasks for students in different grade levels and their impact on students' attitudes toward mathematics learning.

Remark: The designed tasks will be implemented between March and May 2025. The effects of these tasks on the EM students' mathematics learning motivation will be investigated, analyzed, and shared during the conference presentation.

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PP1-25

THE RELATIONSHIP BETWEEN GENDER AND MATH COMPETENCE BELIEFS THROUGH REFLECTED TEACHER APPRAISAL IN JAPAN AND THE U.S.

Kim Megyesi-Brem

Claremont Graduate University, U.S.A., kimberly.megyesi-brem@cgu.edu

Background

Math self-concept is a key determinant of students' short- and long-term academic choices and future academic opportunities in STEM (Heyder et al., 2019; Lauermann et al., 2017). One aspect of math self-concept is math competence beliefs, and research shows that elementary and middle school girls often underestimate their math competence (Mejia-Rodriguez et al., 2021). One potential predictor may be reflected teacher appraisal, or students' perceptions of their teachers' assessment of their mathematical competence (Bouchey & Harter, 2005; Winberg & Palm, 2021). Understanding underestimation of math competence beliefs is important because math self-concept positively and significantly has been found to correlate with math-related career aspirations in many countries worldwide (Goldman & Penner, 2016; Guo et al., 2015; Wang et al., 2019). Lower math self-concept in girls may contribute to the disproportionately low STEM field participation of women in Japan and of math-related fields in the U.S. (OECD, 2023; Pew Research, 2021; Yoshikawa et al., 2018). Bias in teacher evaluations of student competence have been found in studies of elementary and middle school teachers in Germany, Japan, and the U.S., and teacher assessment was found to mediate the relationship between gender and math self-concept among German elementary students (Fennema et al., 1990; Heyder et al., 2019; Nakamura & Isa, 2024; Reschke et al., 2023).

Research Questions

For eighth grade students in Japan and the United States, does reflected teacher appraisal predict math competence beliefs? Do gender and math competence beliefs relate indirectly through reflected teacher appraisal?

Theoretical Framework

In Eccles & Wigfield's (2020) Situated Expectancy Value Theory, teachers are considered socializers, and their beliefs and behaviors influence the ways in which students perceive their own competence. Personal characteristics, such as gender and country, also influence self-assessment.

Methods

The present study used eighth grade data from the Trends in International Math and Science Study 2019 (TIMSS, 2019; N=13,144; Mullis et al., 2020) from Japan (n=4,446) and the U.S. (n=8,698). The variable *reflected teacher appraisal* reflected one question, *"My teacher tells me I am good at mathematics"* with a four-point Likert scale. Confirmatory factor analysis confirmed that three survey items could be grouped in a latent variable, *math competence beliefs* (0.817 to 0.883; Chronbach's alpha = 0.821). An example item is "*I am good at problem solving*." A multivariate linear regression was used to answer the first research question, factoring in math achievement ($R^2 = 0.497$ in Japan; $R^2 = 0.412$ in the U.S.). The structural equation model method was used to answer the second research question.

Findings & Conclusion

Table 1. The relationship between gender and math competence beliefs in Japan and the U.S through reflected teacher appraisal, controlling for math achievement

	Japan		United States	
	B	OIM S.E.	*B*	OIM S.E.
Mediator: appraisal on gender ⇒ MCP				
Path a: female ⇒ appraisal	-0.223***	0.022	-0.145***	0.029
Path b: appraisal ⇒ MCP	0.506***	0.012	0.416***	0.008
Path c: female ⇒ MCP (total)	-0.315***	0.021	-0.163***	0.019
Path c`: female ⇒ MCP (direct)	-0.202***	0.019	-0.103***	0.016
Indirect effect (a x b)	-0.113***	0.012	-0.060***	0.010
% mediated	36%		37%	

Note: Source: Trends in Math and Science Study (TIMSS) 2019 (Mullis et al., 2020); B = coefficient; OIM S.E. = observed information matrix standard errors; MCP = math competence perception; standardized; achievement is controlled for, the mean of five plausible values is used instead of regressions of five plausible values; p < 0.05 = *; p < 0.010 = **; p < 0.001 = ***

The present study found that the relationship between reflected teacher appraisal and math competence beliefs was significant and positive, and larger in Japan (0.518) than in the U.S. (0.419). In addition, the math competence beliefs of female students were significantly lower than of male students (-0.198 in Japan; -0.124 in the U.S.). The greater effect in Japan may reflect the fact that teachers are highly respected in Japan, and possibly the use of normed evaluation by teachers guiding Japanese middle school students to choose a high school matched to their skill level, similar to normative grading practices used elsewhere in East Asia (Bong et al., 2012; Shimizu, 1992). The findings of this study supported prior research that teacher assessment partially mediates the relationship between gender and math self-concept for middle school students in Japan (36%) and in the U.S. (37%; see Table 2; Heyder et al., 2019; Reschke et al., 2023). Reflected teacher appraisal appears to contribute to the way students think about themselves within the field of mathematics to a similar extent in both countries. Efforts should consider ways to change broader sociocultural views about mathematics and gender (c.f. Lee, et al., 2022).

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PP1-26

COMMUNICATING WITH METAPHORS: A LONG-TERM CASE STUDY FOR THIRD GRADE ELEMENTARY SCHOOL STUDENTS

Kensuke Koizumi
Yokohama National University, Japan, koizumi-kensuke-cx@ynu.ac.jp

Ryo Hanzawa
Seya Elementary School, City of Yokohama, Japan, hanzawa.ryo.1009@gmail.com

Ryuta Tani
Tanaka Gakuen Ritsumeikan Keisho Primary School, Japan, r.tani@tanakagakuen.ed.jp

Background and Purpose of This Study

Research on metaphors in mathematics education has primarily focused on their use in instructional materials and explanations for teachers, as well as on the individual cognitive processes of children (Soto-Andrade, 2014). However, there has been no attempt to consider their role in children's interactions with each other in the classroom. For children who are still unsure, having others create good metaphorical expressions might help them understand. And also, for children who already understand (at least, they think so), the process of creating metaphorical expressions and explaining to others is expected to foster empathy by encouraging them to think from the perspective of others, and to deepen their understanding by re-thinking essential elements.

In this study, while reflecting as necessary, we will attempt continuous teaching to encourage the creation of metaphorical expressions in math classes. The purpose of this case study is to clarify the findings and future issues from a year-long lesson practice with third-grade elementary school students. The methods of this study are protocol analysis, questionnaire surveys, and interview surveys.

Overview of This Case Study

This research can be divided into the following three categories. Then, the relationship between the three categories is as follows: (1) and (2) were carried out in relation to each other within the context of educational activities. (3) was carried out based on the continuous practice of (1) and (2).

(1) Interventions by teacher ("as necessity") in math class

In math classes, we make situations where we ask students, "Can you explain ~~ by using a metaphor?". We think that when encouraging students to explain through metaphors, it is important to create situations where some "normal" explanation does not convey the concept well and is difficult for them to understand. Therefore, it is more important for the intervention to be based on the teacher's immediate judgment rather than being decided in advance.

(2) Connections that also focus on overall educational activities

This category can be divided into two things. The first is an exploration from a linguistic perspective to identify any learning content that can be focused on the basic significance and role of metaphor. We attempted to make cross-curricular connections with Japanese language classes. The second involves expanding the use of metaphors beyond math classes. For example, it is intended to utilize typical situations such as discussions during class activities.

(3) An experimental practice that expected students to show their learning

We would like to investigate whether students attempt to utilize metaphors to explain on their own, even in the absence of teacher intervention. In order to create this situation experimentally, where advanced problems are presented, and students are asked to explain them.

The students have already learned subtraction with borrowing. As an advanced problem, a question involving the calculation of time in a columnar format was presented (figure 1), and they were asked to interpret how to solve it.

While the students were explaining their interpretations of this calculation, there was one student (C1) who strongly insisted that they were not convinced by these explanations. During a discussion on how to reach everyone's consensus, a student used the metaphor of "money" to explain their point (C2). It was an explanation compared to currency exchange, where C2 emphasized that 'the appearance changes, but the content remains the same,' which is the important point.

After this lesson, many students wrote in their reflections that C2's explanation was great to understand. Interviews were conducted with several students, including C1 and C2, as well as those who showed remarkable actions in (1) and (2), to investigate what these students were thinking.

Findings

Through this study, both the achievements and challenges have been shown. Children who attempted to use metaphors in their explanations during math classes have indeed emerged. It was revealed that such children have realized the effectiveness of metaphors in simply conveying only the essential elements. However, several challenges were also revealed. Among the metaphors created by the children, many had unclear relationships between the base and the target. However, the process of improving to better expressions was rarely carried out in this case study. Consideration should be given to how to guide the children regarding this issue and how to take their developmental stages into account. Additionally, it is challenging for children to recognize the limitations of metaphors and to demonstrate empathy while explaining, which are also issues to be addressed.

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PP1-27

A NARRATIVE STUDY ON MATHEMATICS LEARNING INTERACTION BETWEEN PARENTS AND STUDENTS IN LOWER ELEMENTARY SCHOOL

Bo-myoung Ok
Dankook University, South Korea, ok0430@hanmail.net

Jae-woong Rim
Naejeong Elementary School, South Korea, modoosong@naver.com

Introduction

> Every day, he gives me a math problem, I solve it, and he grades it. The problem is a variation on a problem he solved at school. For example, my son asks me to count exactly how many circles there are and write the answer. [1)]

Professor Heo Jun-yi, a Korean American mathematician, said in an interview after winning the Fields Medal about studying mathematics with his son. After the interview, when the interviewer asked the accompanying child if he enjoyed the most about what he did with his father, he replied, “multiplication.” It was impressive to know how the mathematician’s father interacted with his elementary school child about multiplication and how his child felt through the interaction.

Mathematical interaction between parents and children refers to verbal and nonverbal interactions between parents and children about solving mathematical concepts and mathematical problems encountered in daily life at home (Kim, 2015). In previous studies, it was found that mathematical interaction between parents and infants had a significant effect on the development of mathematical abilities and the formation of positive mathematical attitudes in infants (e.g., Lee & Kim, 2016; Levin, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010).

In a study by Hwang, Ko, & Tak (2020), it was found that students want to improve their achievement but give up learning mathematics if family resources are limited. This study emphasized that support for family resources should include support for interactions between parents and children as well as economic support. In the lower grades of elementary school, there is a lot of interaction with parents, just like in infancy. A study by Lee & Ok (2023) that examined the causes of math learning abandonment found that parental interactions during the early elementary years are important in helping students form positive experiences and emotions related to math learning.

Therefore, the purpose of this study is to explore the interactions related to math learning between parents and children by analyzing the interview contents of parents in the lower grades of elementary school.

1) Retrieved from http://woman.chosun.com/news/articleView.html?idxno=101162 (2025.2.3)

Method

Semi-structured interviews were conducted with seven parents (5 mothers and 2 fathers) of lower grades of elementary school living in A city in the capital area. City A is a new city composed of large apartment complexes where many younger generations live due to the abundant jobs of industrial complex located nearby.

The method of recruiting study participants was done through the snowballing method, and the interview took place over two months from the end of November 2024 to the end of January 2025. As a data analysis method, the interview transcripts were first read repeatedly to identify key words and concepts that appeared in relation to the research purpose. Open coding was used to identify the context, and axial coding was used to structure each theme that appeared in the context.

Results

When we looked at parent-child interactions in the lower elementary grades, we found that parents who had done well in math were more likely to help their children with math. Even parents who struggled with math in school said they helped their children with math because lower elementary math is not difficult. Most sat at a desk with their child, solving problems from a math workbook and explaining problems the child got wrong or didn't understand. Parents who did well in math in school were more likely to apply their own experiences to their children's math learning.

> Sometimes my child brings a math problem from school. My child asked me to teach him how to solve the problem he couldn't solve at school, but the problem was harder than I thought. I'm a little weak in math, so my husband helps my child with math. (In the interview with mother B)
>
> In elementary school math problems, I'm trying to make my child understand the concept. For my child to be good at math, he must be fundamental, and he must solve a lot of problems, optimize them, and continue to challenge himself in the deeper part. (In the interview with father C)

It was found that parents in the lower grades of elementary school had difficulty in guiding emotional aspects in math learning with their children. Parents did not know what to interact with their children in situations where they expressed negative emotions when they could not solve difficult math problems or when they could not adapt to their parents' math teaching methods.

> My child cried while solving difficult problems. I know that when I have no choice but to tell them what to do, it's stressful for my child, so I actually send him to a private academy. (In the interview with mother D)
>
> When my husband asked her to explain the problem, she suddenly fell on her desk and started crying. My husband was embarrassed and said, "I don't know why she's crying." (In the interview with mother E)

Discussion

As a result of this study, most of the interactions related to math learning at home were that children solve math problems and parents solved errors after scoring. This can be seen as an interaction that emphasizes instrumental understanding rather than relational understanding of mathematics learning content. Relational understanding is knowing all what to do and why and instrumental understanding is applying rules memorized without knowing why (Skemp,1978). Multiplication learning with the son shown in Professor Heo's interview can be said to be an interaction that helps relational understanding. The lower-grade mathematics concept, which parents perceive as relatively easy, is the basis for formalization and abstraction of higher-grade mathematics learning, so relational understanding should be emphasized rather than instrumental understanding.

It was found that there was a very lack of interaction with parents to help form positive experiences and emotions related to math learning. According to a survey conducted by the Korea Foundation for the Advancement of Science and Creativity in 2015, the first thing that elementary school students gave up math was a lack of efficacy and the second was a lack of interest. (Ko, Kim, Kaji, & Choi, 2017). This suggests that interactions with lower elementary students in math learning should lead to feelings like "I like math" and positive experiences like "I did well on my test because I worked on math with my mom."

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PP1-28

A STUDY ON APPLYING IDENTICAL HISTORY OF MATHEMATICS RESOURCES IN DIFFERENT INSTITUTIONS

Yi-Wen Su
University of Taipei, Taiwan, yiwen@utaipei.edu.tw

Takeshi Miyakawa
Waseda University, Japan, tmiyakawa@waseda.jp

Chih-Lun Sung
University of Washington, USA, chihls@uw.edu

Introduction

"To promote cultural access to mathematics" is a key focus and goal of the HPM Group (International Study Group on the Relations between the History and Pedagogy of Mathematics). Over the past 40 years, integrating the history of mathematics into mathematics education has become a widely studied area, involving new pedagogical practices and specific research activities. Today, the history of mathematics is considered a valuable resource for didactic intervention in all aspects of mathematics education (Barbin, Guillemette, & Tzanakis, 2014; Chorlay, Clark, & Tzanakis, 2022).

In mathematics problem solving, individuals often encounter questions where numbers are obscured by water stains, and the data cannot be identified. In such cases, the unknown numbers must be inferred from the available clues. Problems like this are referred to as "Worm-eaten calculations" (Mushikuizan) in Japan. The term originates from the fact that paper in ancient Japan was prone to being eaten by insects, which led to the creation of this type of problem (Su & Miyakawa, 2024). Japan is a popular destination for Taiwanese tourists, and many Taiwanese students are also interested in Japanese culture. In this study, the research team utilized the identical Japanese history of mathematics resources at different educational stages and investigated the best ways to incorporate historical resources.

Theoretical and Methodological Perspectives

This study adopts the perspectives proposed by the Anthropological Theory of the Didactic (ATD; Chevallard, 2019). Within this framework, we argue that the nature of mathematical knowledge varies depending on the institution. The purpose of ATD is to help us perceive the observable world, go beyond it, and model it in order to understand and explain the didactic processes in any institution (Chevallard et al., 2022). In our case, the institutions considered are schools in Taiwan at various stages of education. We believe that what is taught at schools originates in other institutions, and the following process of didactic transposition is often involved: scholarly knowledge $\leftrightarrow$ knowledge to be taught $\leftrightarrow$ taught knowledge $\leftrightarrow$ learnt knowledge (Chevallard & Bosch, 2020). We discussed "Worm-eaten calculations" from Japanese traditional mathematics (Wasan) texts. The research team designed history of mathematics resources to be taught at schools, and then observed the in-service teachers' taught knowledge and the students' learnt knowledge. Finally, we consider that the mechanism behind these differences is governed by the system of conditions and constraints prevailing in the institution (Miyakawa & Su, 2025). The research questions are as follows:

- What are the results of applying the "Worm-eaten calculations" theme in different institutions, and what are the conditions and constraints?

Results

The research team used the identical history of mathematics resources at different stages of education, including elementary schools, middle schools, and the university. Through practical analysis involving 44 first-grade elementary school students from two classes, the experimental teaching of integrating "Worm-eaten calculations" into a two-digit addition and subtraction topic received positive feedback from both students and parents (Su, 2023). By introducing the tradition of Japanese "bequeathed problems" and "Mushikuizan" to 21 university students, we found that the theme enabled students to experience three aspects: mathematical thinking, the cultural experience of mathematics, and an understanding of mathematics (Su & Miyakawa, 2024).

After the previous studies, the research team modified the university version of the "Worm-eaten calculations" worksheet and then observed in-service middle school teachers' taught knowledge and students' learnt knowledge. Due to space limitations, we will only report the results briefly. The research participants included 52 eighth-grade middle school students. A pretest-posttest "Students Like Learning Mathematics Questionnaire," retrieved from TIMSS 2019 (Martin, von Davier, & Mullis, 2020), was used, with a 4-point Likert scale.

The results of the pre- and post-surveys did not show significant differences. Some students directly stated "I don't like math" or "I really like math" in the reason section. This suggests that applying the history of mathematics in a short period of time is unlikely to change middle school students' established attitudes toward math. Both experimental teachers supported integrating historical materials but noted that, even though the "Worm-eaten" problem from the ancient text only involved division (__ __23. __ __ ÷ 37 = __ __.23), it still proved challenging for students. The researchers reflected that the worksheet should be simplified to strike a balance between being both engaging and educational, allows students to appreciate mathematics by exploring its cultural aspects.

Conclusion

Implementing original historical sources to investigate their educational effects in the classroom, thereby enhancing and deepening reflections on the teaching and learning of mathematics, is one of the main areas of research interest and activity in the HPM domain (Chorlay, Clark, & Tzanakis, 2022). Our findings highlight the potential of implementing the identical history of mathematics resources across different institutions. Through this practice, the goal for future research is to arrange history of mathematics resources in a way that makes them more attractive and increases the learning interest of middle school students.

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PP1-29

EXPLORING AI IN MATHEMATICS EDUCATION FROM THE PERSPECTIVE OF EDUCATIONAL EQUITY AND INCLUSION

Ryoonjin Song
Hanyang University, South Korea, srj430@hanyang.ac.kr

Introduction

As digital technology advances, the need for AI tools is being highlighted in education. In particular, the Korean government emphasizes educational innovation by supporting personalized learning. In response to these social and educational needs, AI digital textbooks are set to be introduced in schools starting in 2025. AI tools offer the advantage of providing personalized learning experiences adapted to various cultural factors (Arroyo et al., 2014; Walkington & Bernacki, 2019; Wang et al., 2020). This advantage is expected to contribute to educational equity and inclusion by supporting students from diverse backgrounds who have often been marginalized in traditional education. From this perspective, the purpose of this study is to explore the potential impact of AI in mathematics education on educational equity and inclusion.

Method

This study conducted a five-step scoping review, consisting of (1) Identifying the research question, (2) Identifying relevant studies, (3) Study selection, (4) Thematic categorization, and (5) Collating, summarizing, and reporting results (Munn et al., 2018). This procedure was adapted from the framework proposed by Arksey and O'Malley (2005) to better align with the objective of this study and present the qualitative analysis results through thematic categorization (Smith et al., 2023).

Results

Realization of Personalized Learning

In traditional mathematics classrooms, both teachers and students are expected to teach and learn the same lessons despite students' diverse backgrounds, such as achievement levels, learning needs, and styles. However, AI tools allow students to receive adaptive, personalized instruction (Khosravi et al., 2022). It has been reported that these tools have positive influences on both academic achievement and students' affective domain (Arroyo et al., 2014). The strengths of AI tools can promote educational equity by implementing excellence in education, especially for students who are marginalized or left behind in mathematics education (Varsik & Vosberg, 2024; Walkington & Bernacki, 2019; Wang et al., 2020).

Breaking Language Barriers

Previous studies have reported that students face significant challenges when the language used in school is not their native language. This is particularly problematic in mathematics which involves abstract concepts. Students learning mathematics in a non-native language may struggle with deep conceptual understanding (Moschkovich, 2002; Robertson & Graven, 2019). However, AI tools can provide conceptual explanations and contextual examples in the student's native language (Athanassopoulos et al., 2023; Varsik & Vosberg, 2024). In this perspective, if AI tools are properly integrated then they can facilitate deeper comprehension of abstract mathematical concepts. In multilingual mathematics classrooms, well-structured AI-driven language support can help linguistically disadvantaged students gain access to quality mathematics education.

Enhancing Cultural Relevant Resources

It is reported that culturally marginalized students have difficulties accessing school mathematics because of cultural differences. Therefore mathematics teachers should play a crucial role in lowering the barriers to school mathematics by using students' diverse cultural resources as scaffolds for learning (Aguirre et al., 2013; Nasir et al., 2008). However, offering adaptive instruction to all students based on their cultural backgrounds can be overly demanding and impractical for teachers. At this point, AI tools could be a game changer in implementing culturally relevant teaching in multicultural mathematics classrooms. AI tools can bridge this gap by dynamically providing culturally relevant resources (Pawar and Khose, 2024). This, in turn, enhances fair access to mathematics education, promoting educational equity.

Reducing Socioeconomic Gaps

AI tools can offer high-quality education to students with limited resources due to social and economic disparities. Increased government support for digital devices could allow students from all socioeconomic backgrounds to access quality mathematics education (Muralidharan et al., 2019; Nickow et al., 2020; Varsik & Vosberg, 2024). Considering that mathematics has been regarded as a gatekeeper for college admission and career opportunities, AI tools can be innovative points for educational equity bridging the gap (Nasir et al., 2008; Varsik & Vosberg, 2024).

Discussion

Even though AI tools offer many benefits, we face several challenges, such as algorithmic bias, teacher roles in AI-supported environments, and ethical concerns like data privacy when AI tools are implemented. These aspects require further research and careful policy considerations (Kim et al., 2023; Varsik & Vosberg, 2024).

Conclusion

From the literature review, the researcher explored the impact of AI in mathematics education from the perspective of educational equity and inclusion and its limitations. However, despite the many positive impacts of using AI tools in mathematics education, its implementation requires careful educational planning and deliberate efforts to overcome the challenges discussed earlier. Furthermore, empirical research in AI mathematics education should be actively conducted across all school levels in the future, and discourse on its implications and limitations should be encouraged. These efforts will ensure that AI technology transcends mere instructional tools and provides an equal and inclusive learning environment.

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MEMO

Poster Presentation 2

KOREA 2025
EARCOME9

The 9th ICMI-East Asia Regional Conference on Mathematics Education

PP2-01

STUDENTS' PERSPECTIVES ON THE RELATIONSHIP BETWEEN QUADRATURE FORMULAE IN ARITHMETIC

Ryuta Tani
Tanaka Gakuen Ritsumeikan Keisho Primary School, Japan, r.tani@tanakagakuen.ed.jp

Background, Purpose and Method

Concise, clear and integrated perspectives are important in mathematics education. Furthermore, the Japanese curriculum guidelines emphasize the importance of 'integration'. There are three types of integration: integration of sets, integration by extension and integration by complementation.

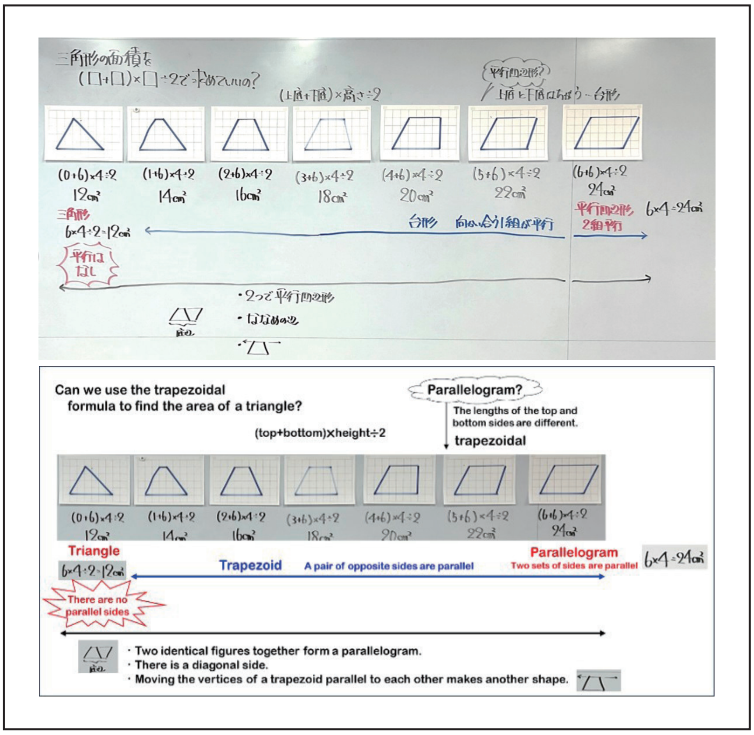

Figure 1. Blackboard in this class (Tani2024)

Referring to previous research, lessons on finding the area of a triangle using the trapezoidal formula have been conducted with the aim of developing an integrated way of thinking. The area of a trapezoid can be calculated by '(upper base + lower base) x height / 2'. If the upper side is 0 cm, the area of a triangle can also be found as '(0 + lower bottom) x height / 2'. And it is reported that through this lesson, the students realized the advantages of thinking in an integrated way. In contrast, Tani (2024) pointed out the following two points. (i) The more correctly students understood the definition of a trapezoid, the more resistant they were to find the area of a triangle using the trapezoidal formula. (ii) Many of the students who answer that it is acceptable to use the trapezoidal formula to find the area are not necessarily thinking in an integrated manner, as their rationale is that ‘the resultant answer will be the same’. Although the difficulty of thinking integrally was revealed through Tani (2024), it remains unclear what structure students consider the quadrature formula to be. And, to the best of our knowledge, this has not been fully clarified in other previous studies.

Therefore, the aim of this study is to determine how students who have been taught to find the area of a triangle using the trapezoidal formula relate it to the quadrature formula. To achieve this objective, the students’ notes in the Tani (2024) lesson are analyzed again and interviews are conducted with several students.

Outline of This Class

This lesson was given after the study of the areas of triangles, parallelograms and trapezoids. They found the area of a trapezoid and increased the length of the upper base by 1 cm. Then, when they reached a parallelogram, they discussed whether they could use the quadrature formula for trapezoids to find it. Afterwards, the length of the upper base was shortened by 1 cm and when it became a triangle (with a top of 0 cm), the students discussed whether they could use the quadrature formula for trapezoids in the same way as before (Figure 1).

Research Findings

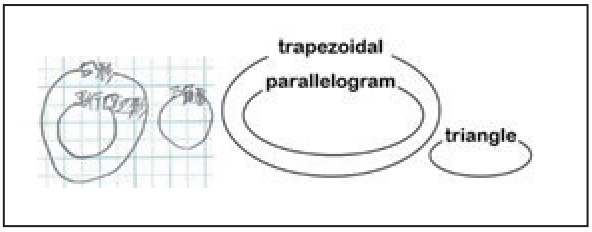

Figure 2. Notebook of Student 01

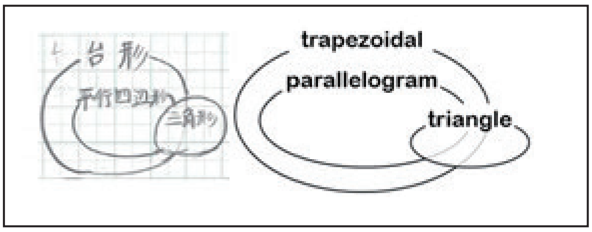

Figure 3. Notebook of Student 02

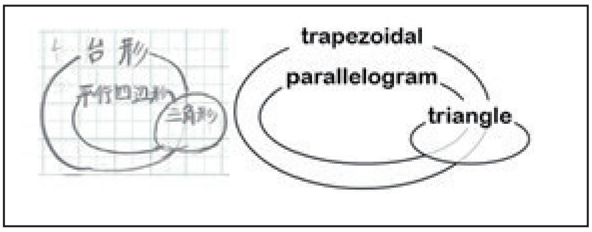

Figure 4. Notebook of Student 21

After the lesson, students described in their notebooks the relationships between the quadrature formulae for trapezoids, parallelograms and triangles. Three students were extracted from the data (Figures 2-4). The student in Figure 2 answered that she could find the area of a triangle using the trapezoidal formula, but when the relationship was represented in the diagram, it became clear that she considered trapezoids and triangles to be different companions. The reason for this was that although the answer would be the same, triangles are not in the same group as trapezoids as they do not fit the definition of a trapezoid.

The student in Figure 3 could use the trapezoid formula to find the area of a triangle, but not the definition of a trapezoid, so he thought that some of them were companions and represented them in this figure.

The student in Figure 4 thought that trapezoids and triangles were companions because they both form a parallelogram when two are combined and represented in this diagram.

Conclusion

It was evident that students were maintaining the relationships they had previously learnt and trying to incorporate new ones into their structure. Therefore, finding the area of a triangle using the trapezoidal formula does not provide an opportunity to change the perspective and re-comprehend it in an integrated way. In the future, it is necessary to research what kind of teaching materials create opportunities to re-comprehend in an integrated way.

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PP2-02

THE IMPACT OF DIFFERENT PROMPTS ON CREATIVE PERFORMANCE IN PROBLEM POSING TASK

I-TIEH, Lin

National Taiwan Normal University, Chinese Taipei, vanessa90119@gmail.com

Introduction

The purpose of this study is to investigate which types of prompts, as intervention strategies, can effectively enhance students' creativity in problem-posing tasks, particularly in terms of flexibility and originality. The goal is for these prompts to effectively support students in generating interesting or critical problems and demonstrating creativity in problem-posing tasks.

Methodology

Participants

A total of 124 students from two public high schools in northern Taiwan were included: 37 eleventh-grade students from one school and 87 tenth-grade students from another. After excluding blank or invalid responses, a total of 113 completed test papers were analyzed.

The mathematical problem posing test

The mathematical problem posing test used in this study was designed based on the framework proposed by Stoyanova & Ellerton (1996) and the study by Van Harpen & Sriraman (2013), utilizing an unstructured geometric situation. Additionally, modifications were made to the prompts used in Van Harpen & Sriraman (2013) study. The test guided students to pose three mathematical problems through three sub-questions. Students were asked to pose a mathematical problem based on a given geometric situation, a significantly different problem from their first one and a highly unique mathematical problem. To further explore the influence of additional prompts, three different versions emphasizing a distinct additional prompt. Version A included the prompt "You may provide additional information or constraints."; Version B included the prompt "Formulate a problem as if designing a test question to challenge your peers."; and Version C encouraged students to "Formulate a problem that allows for multiple solutions." The test was administered in a 40-minute session, with the three versions randomly distributed among students.

For flexibility and originality scoring, this study adopted the method proposed by Leikin (2013). A one-way analysis of variance (ANOVA) was conducted to examine the effects of different prompts on flexibility and originality, while a Chi-square test was employed to determine the influence of different prompts on the types of questions generated by students.

Results

The effects of different prompts on flexibility and originality

Table 1. The mean and standard deviation (SD) of flexibility and originality

	Mean (SD)		
	Version A (N=38)	Version B (N=40)	Version C (N=35)
flexibility	17.44 (SD=6.46)	17.51 (SD=8.10)	18.48 (SD=6.08)
originality	3.30 (SD=5.02)	3.52 (SD=5.59)	1.82 (SD=4.22)

The effects of different prompts on flexibility (p=.78) and originality (p=.29) were not statistically significant. As no statistically significant differences were found, further analysis was conducted to explore the distribution of question types generated by students under different prompts. This study classified the 237 feasible problems posed by students into five distinct categories. The distribution of feasible problems across these categories is presented below.

Table 2. The mathematical problem posing test categories distribution (Chi-square test)

Categories	Distribution of problems (Expected)		
	Version A	Version B	Version C
Analytical geometry	7.9% (10.9%)	10.8% (11.0%)	14.1% (11.0%)
Lengths	26.3% (34.2%)	39.8% (34.2%)	35.9% (34.2%)
Area	36.8% (30.4%)	22.9% (30.4%)	32.1% (30.4%)
Angles	9.2% (10.5%)	13.3% (10.6%)	9.0% (10.5%)
Involving other figures	19.7% (13.9%)	13.3% (14.0%)	9.0% (14.0%)

The distribution of question types generated by students under different prompts were not statistically significant (p=.24).

Discussion

Since the test was divided into three versions, each version included only around thirty participants. Combined with the scoring method, this resulted in large variations in the mean originality scores within the same version. Consequently, although Versions B and C exhibited differences in their mean originality scores, these differences did not reach statistical significance. Future research could address this limitation by increasing the sample size and refining the scoring method. Furthermore, Version C yielded the highest performance in flexibility but the lowest in originality. This may be due to the nature of the phrase multiple solutions, which might have led students to prioritize the quantity of responses over their quality. Finally, while the small sample size may have contributed to the non-significant distribution of question types across different prompt conditions, it is noteworthy that Version A showed a much higher observed frequency than expected in the category *Involving other figures*. This suggests that the prompt in Version A may indeed influence the likelihood of generating questions in that category. Future studies could expand the sample size to further investigate this potential effect.

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PP2-03

A NEW APPROACH OF MATHEMATICAL PROBLEM SOLVING ON THE PREMISE OF USING SCIENTIFIC CALCULATOR: BYOND ALGORITHMIC THINKING/COMPUTATIONAL THINKING

Akio Matsuzaki
Saitama University, Japan, makio@mail.saitama-u.ac.jp

Kazuhiko Imai
Tokyo Gakugei University International Secondary School, Japan, imakazu@u-gakugei.ac.jp

Our project is supported by industry-academic collaborative project between Saitama University and CASIO Cooperation, "Mathematics Teaching on the Premising of Using Scientific Calculator and Its Global Expansion" (project representative: Matsuzaki Akio), started from June 2020. An aim of this project is to practice mathematics teaching using scientific calculator naturally. Mathematics teachers at secondary level in this project member plan and implement mathematics lessons or workshops. Our project members develop some teaching materials on the premise of scientific calculator. We set a research question as follow: Is it possible that mathematical problem solving on the premise of using scientific calculator realize a new approach beyond algorithmic thinking/computational thinking? In this presentation we introduce outline of the project and its products.

Keywords: Algorithmic thinking, computational thinking, Scientific calculator

Project Outline: Mathematical Problem Solving on the Premise of Using Scientific Calculator

Our project is supported by industry-academic collaborative project between Saitama University and CASIO Cooperation, "Mathematics Teaching on the Premising of Using Scientific Calculator and Its Global Expansion" (project representative: Matsuzaki Akio), started from June 2020. An aim of this project is to practice mathematics teaching using scientific calculator naturally. The mathematics teachers at secondary level in the project member plan, and implement mathematics lessons and workshops (https://edu.casio.com/ja/products/events/case02/).

Algorithmic (Computational) thinking (AT/CT) is a key element of the new digital literacy, and might contribute to the developments of new mathematics in the school curriculum (Max, 2021). The prospects of our project are mathematical problem solving and mathematics teaching using scientific calculator anytime. Research question is as follow: *Is it possible that mathematical problem solving on the premise of using scientific calculator realize a new approach beyond AT/CT?*

Towards a New Approach of Mathematical Problem Solving Beyond Algorithmic Thinking/Computational Thinking

For stators, our project members referred the problems from the 69th Saitama Senior High School Standard Test 2020 developed by Saitama Senior High School Mathematics Education Study

Group, and categorize the problems to three types as follows: Category I: It is able to solve *instantly* using scientific calculator, Category II: It is able to solve *by devising* using scientific calculator, and Category III: It is *difficulty* to solve using scientific calculator. In addition, we divide Category II into three types as follows: Type (a): It is able to solve by devising function(s) and/or conditional expression(s) or using formula(s), type (b): It is able to solve the problems by devising usages of scientific calculator, and Type (c): It is able to solve by examining and/or interpreting output of scientific calculator (Imai, 2021). For example, the following problem is categorized the type II-(a);

<u>Mathematics I + A</u>

8. Fill in the blanks.

(2) The greatest common divisor of 36, 48, and 84 is ☐, and the latest common multiple of 36, 48, and 84 is ☐.

(Saitama Senior High School Mathematics Education Study Group, 2020)

We will try to use the GCD function to find the greatest common divisor of the numbers 36, 48, and 84. At that time an error message ‘Syntax ERROR’ is displayed on the screen. Here a reason why output the error message is that the GCD function can treat two arguments only. So we will try to insert the GCD function into the GCD function to find the greatest common divisor of the numbers 36, 48, and 84. In this time the greatest common devisor of the numbers 36, 48, and 84, ‘12’, is displayed on the screen (Fig.1). This problem solving of great common divisor of the numbers 36, 48, and 84 is categorized type II-(a): It is able to solve by devising function. Applying limits and/or constraints of scientific calculator to mathematical problem solving, we hope that mathematical problem solving on the premise of scientific calculator as a new approach will withdraw a different thinking from algorithmic (computational) thinking (AT/CT).

Figure 1. The case of inserting the GCD function into the GCD function

Acknowledgement

This work is supported by industry-academic collaborative project between Saitama University and CASIO Cooperation “Mathematics Teaching on the Premising of Using Scientific Calculator and Its Global Expansion” (project representative: Matsuzaki Akio) from June 2020.

PP2-04

EXPLORING PEDAGOGICAL DILEMMAS IN AN ITS-BASED MATHEMATICS COURSE

Eun Young Cho

Korean Bible University, Republic of Korea, ceyceyoung@gmail.com

This study aimed to explore the instructional dilemmas experienced by a mathematics instructor during the implementation of an ITS in a general education course at K University in Seoul, through qualitative analysis of teaching reflection journals. In the course, the AI-based education system ALEKS was used to support a personalized learning path. The analysis identified four major instructional dilemmas in implementing ITS in a mathematics course in general education: addressing diverse student backgrounds, balancing time between instruction and system use, managing technical disruptions, and handling the ongoing burden of lesson preparation. Effective implementation of ITS requires instructors' pedagogical and practical expertise, along with institutional support systems.

Keywords: Intelligent Tutoring Systems, ITS, mathematics education, general education, instructional dilemmas, pedagogical competence

Introduction

Since the curriculum reform integrating science and humanities tracks, concerns have been raised regarding the decline in basic mathematical competence of incoming university students (Shim & Ko, 2019). Consequently, there is an urgent need to develop new teaching and learning strategies to strengthen students' mathematical competence in general education mathematics courses attended by students from diverse academic backgrounds. Compared to elementary and secondary education (Kumor et al, 2024; Sung, 2023), studies and discussions on the adoption of Intelligent Tutoring Systems (ITS) in higher education remain limited.

Although AI-based ITS, which reflect learners' diverse levels and provide individualized learning paths, are gaining attention, research on actual implementation cases and the pedagogical challenges that arise during the process still remains insufficient. This study explored the pedagogical dilemmas that an instructor had experienced while using ITS to support students' mathematical understanding in a general education mathematics course.

Body

This study examined a general education mathematics course conducted at K University in Seoul in 2025, with 24 students participating. The instructor wrote reflective journals on course preparation, operation, and challenges during the course. These journals were qualitatively analyzed to identify key dilemmas and instructional strategy changes. The analysis, centered on challenges, instructional strategies, and course design adjustments, revealed **four major dilemmas**.

The 15-week course ran once a week for 100 minutes, combining lectures and self-directed learning using ITS, specifically ALEKS. The first half of each class consisted of lectures on mathematical concepts and their context, while the second half was dedicated to individual learning through

ITS. Topics covered included expressions and equations, matrices, probability and statistics, and calculus. Since ALEKS was an English-based system, students used Chrome's translation function to support their learning.

The first dilemma was how to design a class that could accommodate the varying academic backgrounds of students from diverse majors. For students with insufficient fundamental knowledge, the personalized learning paths provided by ITS were not sufficient on their own. This led to the second dilemma: how to balance the time spent on explaining mathematical concepts and the time allocated for using ITS. Since some students required additional explanations for the problems presented in ITS, the instructor had to continuously adjust the proportion between lectures and ITS activities.

The third dilemma related to technical issues such as system access errors and internet instability, which disrupted planned activities and required flexible lesson adjustments. The fourth dilemma was the ongoing burden of preparing ITS-based lessons. Even after becoming familiar with the system, the instructor had to continually review the difficulty of ITS-based questions and learning time, which consumed significant time and effort.

These dilemmas indicate that integrating ITS into instruction requires rethinking the overall course structure and continually adjusting instructional strategies to address system limitations. In other words, the use of ITS demands a redefinition of the instructor's role within the context of mathematics education as general education.

Conclusion

This study demonstrated that ITS-based mathematics education requires instructors to move beyond simply using the system as a tool, in order to actively engage in course design and pedagogy throughout the teaching process. While ITS excels in providing individualized learning paths, supplementary explanations by instructors and careful adjustments to address learning gaps among students are essential for fostering a deep understanding of mathematical concepts. In particular, in general education settings where students come from diverse academic backgrounds, the unilateral application of ITS can undermine instructional effectiveness, making the instructor's course design capabilities even more critical.

Thus, effectively utilizing ITS necessitates instructional strategies grounded in instructors' practical expertise, along with thorough preparation and flexible course management skills. To promote the broader adoption of ITS-based mathematics education, institutional support measures, such as professional development for instructors, must also be established. This study shows that ITS can serve not merely as a tool but as a catalyst for enhancing instructors' pedagogical and practical competencies, offering insights for the effective integration of ITS into mathematics education.

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PP2-05

CHILDREN'S OWN BUNDLE-NUMBERS WITH UNITS MAY REACH THE UNITED NATIONS DEVELOPMENT NUMERACY GOAL

Allan Tarp
MATHeCADEMY.net, Denmark, Allan.Tarp@gmail.com

Counting Many with Bundles, Children Deserve a Bundle-Number with Units Curriculum

"No, that is not four, that is two twos". Said a 3year old child when asked "How many years next time?"; and when seeing four fingers held together two by two. This statement will change mathematics education forever since, as educated, essence is all we see. But as uneducated, the child sees what exists, bundles of twos in space, and two of them when counted in time. The number 'two' thus exists both in space and in time. In space, 2 exists as 2s, a space number, a bundle of 2s, a 2-bundle, which can be united with a 3-bundle. Either horizontally to a (2+3) bundle, a 5-bundle, or vertically to a stack of 2B1 2s or a stack of 2B-1 3s with B for bundle. In time, 2 exists together with the unit that was counted, as 2 units, a time-number, or a counting-number. So, 2+3 is 5 only with like units. Without units a counting-numbers are operators to be multiplied with units to become totals that can be added if the units are the same. On my hand, a collapsed V-sign shows that 1 1s + 1 1s = 1 2s, which together with a V-sign's 2 1s total 1 2s + 2 1s = 1 4s, and not 3 3s as expected if 1+1 = 2.

A01. Bundle-counting with units and using snap-cubes or a ten-by-ten BundleBundleBoard, 2 3s is 2 bundles with 3s per bundle. So, the per-number 3s exists in space and the counting-number 2 in time. The Algebra square reunites unlike and like counting- & per-numbers (fig. 1). Polynomials use bundle-counting with units. 43 = 4*B + 3*1 = 4B3 tens, and 543 = 5BB4B3 tens. Bundle-numbers falsify '1+1 = 2' with 2 V-signs showing that 1 1s + 1 1s = 1 2s and 2 1s + 1 2s = 1 4s, and not 3 3s.

A02. Flexible Bundle-counting in space. Space-count five and ten fingers in 2s, 3s, 4s and 5s. 5 = 1B3 = 3B-1 = 2B1 = 1BB0B1 2s, and Ten = 2BB0B2 = 1BBB0BB1BB0 2s. And T = 38 = 3B8 = 2B18 = 4B-2. T = 35+46 =3B5+4B6 = 7B11 = 8B1. T = 6*28 = 6*2B8 = 12B48 = 16B8 = 168. And T = 4507 = 4BBB 5BB 0B 7, T = 4*B^3 + 5*B^2 + 0*B + 7*1. Place value and carrying is unneeded.

A03. Add and subtract 1digit numbers counted in half-bundles. T = 6+7 = ½B1 + ½B2 = 1B3 = 13. T = 4+7 = ½B-1 + ½B2 = 1B1 = 11. T = 3+4 = ½B-2 + ½B-1 = 1B-3 = 7. And T = 8-6 = ½B3 - ½B1 = 3-1 = 2. T = 6-4 = ½B1 - ½B-1 = 1 - -1 = 2 (so, - - = +). T = 6-8 = ½B1 - ½B3 = 1-3 = -2.

A04. Time-counting fingers in ½B, "1,2,3,4,5,6" no! "0B1, 0B2, 0B3, 0B4, 0B5 or ½B0, ½B1". Time-count from 88 to 100: "8B8, 8B9, 8Bten or 9B0, …, 9B9, 9Bten or tenB0 or 1BB0B0".

A05. Digits are icons. 4 strokes as a 4-icon: I I I I → IIII → 4. And 5 as a 5-icon: I I I I I → IIIII →5.

A06. Operations are icons also. Push-away and -back to lift to stack, (division & multiplication), 6/2 means 'from 6 push-away 2s to lift', so 6 = 3x2 = (6/2)x2, T = (T/B)xB (the recount-formula). Pull-away and -back (minus and plus) to get decimals, fractions and negatives. 7 = 3B1 = 3½B = 4B-1 2s.

A07. Recounting between icon and tens. "? 5s gives 40": u*5 = 40 = (40/5)*5, so u = 40/5, i.e., "To Opposite Side with Opposite Sign". 6 7s = ? 8s and 6 7s = ? tens leads to division and multiplication tables where 6 7s = 6*7 = (B-4)*(B-3) = From BB, pull-away 3B & 4B and pull-back the 4*3 pulled-away twice = 3B12 = 4B2 = 42. So (B-4)*(B-3) = BB - 3B - 4B + 4*3. Here, minus * minus is +.

A08. Recounting physical units gives per-numbers as 2$/5kg. 20kg = (20/5)*5kg = (20/5)*2$ = 8$. Meter = (meter/second)*second = speed*second. Fractions with like units: 2$/5$ = 2/5. Trigonometry in a stack: height = (height/base)*base = tan(Angle)*base. Pi = n*tan(180/n) for n high enough.

A09. Bundle-bundles are squares. 3 3s= 1BB 3s= 1BB2B1 2s= 1BB-2B1 4s. So, 1BB2B1 = next BB.

A10. Squaring stacks. T = 6 4s = 1BB where B=√(6*4). Guess 1: '(6-1) (4+1)s' or '5 5s', since ½(6-4) = 1. The empty 1-corner needs two 't 4s' stacks, and t*4 = ½ gives t = 1/8. Guess 2: '4.9 4.9s'.

A11. Solving quadratics. A (u+3) square has two squares and stacks: (u+3)^2 = u^2 + 3^2 + 2*3*u = u^2 + 6*u + 9. If u^2 + 6*u + 8 = 0, all disappears but 1, so, (u + 3)^2 = 1, so u = -4 or u = -2.

A12. Adding next-to and on-top or reversed. 2 3s + 4 5s = ? 8s. Here integral calculus adds areas, and recounting change units. 2 3s + ? 5s = 3 8s. Here ? = (T2-T1)/5 = ΔT/5 roots differential calculus.

A13. Adding per-numbers & fractions. 2kg at 3$/kg+ 4kg at 5$/kg=(2+4)kg at (3*2+5*4)/(2+4) $/kg. And, 2 apples with ½ red + 3 apples with 2/3 red = (2+4) apples of which (2*½+3*2/3)/(2+3) red. Integral calculus adds piecewise or locally constant per-numbers.

A14. The Algebra square. The 'Algebra Square' reunites unlike and like unit- & per-numbers

Calculations unite/*split Totals in*	Unlike	Like
Unit-numbers m, s, kg, $	T = a + n *T – n = a*	T = a * n *T/n = a*
Per-numbers m/s, $/100$ = %	T = ∫ f dx *dT/dx = f*	T = a^b $\sqrt[b]{T}$ = *a* *loga(T) = b*

Figure 1. The Algebra Square shows the ways to reunite unlike and like unit- and per-numbers

A15. Fact, fiction & fake models. Fact 'since-then' models quantify and predict predictable quantities by using factual numbers and formulas. Typically modeling the past and the present, they need to be checked for truth and units. Fiction 'if-then' models quantify and predict unpredictable quantities by using assumed numbers and formulas. Typically modeling the future, they need to be supplied with scenarios building on alternative assumptions. Fake 'what-then' models quantify and predict unpredictable qualities by using fake numbers and formulas or by adding without units (Tarp, 2001).

A16. 'Existence-based' math (Tarp, 2018) will allow a communicative turn in the number-language as in the word-language in the 1970s (Widdowson, 1978). Using children's own bundle-numbers with units thus represents a paradigm shift (Kuhn, 1962) that opens new areas for research and innovation; as well as self-organized pre- and in-service teacher training at MATHeCADEMY.net.

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PP2-06

JOURNAL WRITING IN JUNIOR COLLEGE LEVEL CLASSROOMS: EXPLORING MULTIMODAL EXPRESSIONS AND REFLECTIVE PRACTICES

Nan Dai

Anglo Singapore International School, Thailand, charles.d@anglosingapore.ac.th

Ban Har Yeap

Pathlight School, Singapore, Anglo Singapore International School, Thailand, banhar.yeap@pathlight.org.sg

Abstract: This paper examines the diverse modes of journal writing employed by junior college students, including symbols, visuals, and written words. The study also highlights the reflective elements present in the journals of high-achieving students, demonstrating how such practices can lead to a deeper understanding of mathematical concepts. The findings suggest that incorporating reflective journal prompts can benefit all students, regardless of their initial engagement with the activity. Moreover, the research underscores the potential for journal writing to enhance student-teacher relationships and provide a platform for individualized attention.

Keywords: journal writing, reflective practice, mathematical understanding, student-teacher relationship, multimodal expression

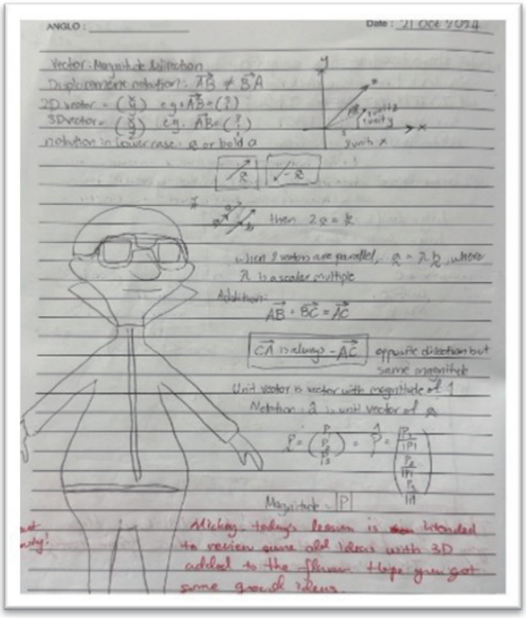
Introduction

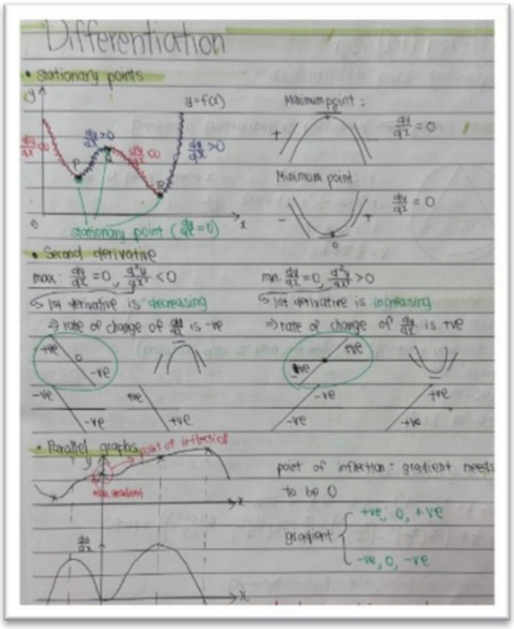
This study of student journals in junior college level (Year 11 &12) mathematics classrooms revealed diverse modes students use to communicate their thoughts and ideas (Chien, 2012). This group of students has developed a journal writing routine in every mathematics class over the past two years. In collecting data over the past two years, we observed students incorporating their creativity and developing their unique style insights into their cognitive processes and engagement in the mathematics classroom at the junior college level. Through this study, we would like to see how journal writing plays a crucial role in a mathematics classroom at the junior college that allows students to become more reflective in their learning. Hence, students can develop a deeper conceptual understanding of learning mathematics and how journal writing is a good practice for any process-driven Mathematics classroom.

Modes of Communication in Journaling

Students are seen to use various modes of communication to express their mathematical ideas (Morgan et al., 2014). These include: Symbolic representations: Students may utilize mathematical symbols, equations, and diagrams to convey their understanding of concepts. Visual elements: Illustrations, graphs, and other visual aids can help students communicate their ideas more intuitively and engagingly. Written narratives: Traditional entries allow students to articulate their thoughts, reflections, and learning experiences.

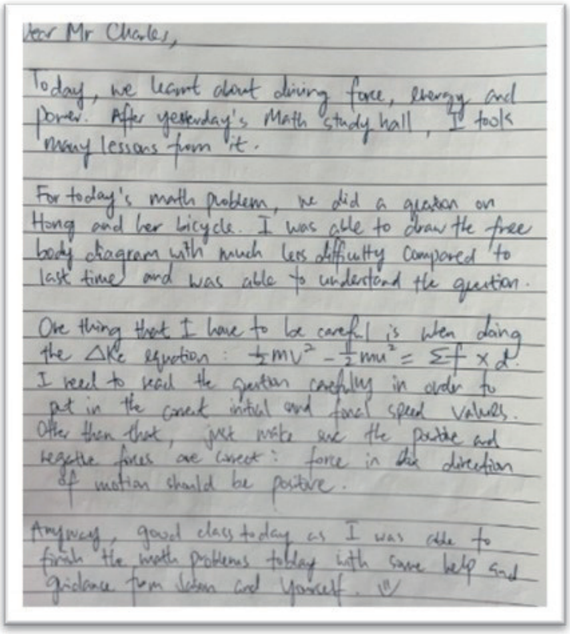
We will now showcase some examples of student journal entries in these respective modes of communication.





We have an example in Figure on the left, where a student used a symbolic representation to explain their understanding of a mathematical concept.

Next, in the Figure on the right, we have an example of a student using visuals to demonstrate their understanding of a problem.



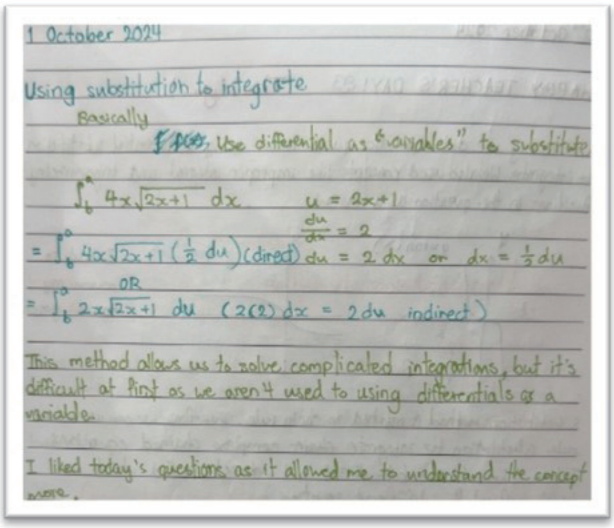
Dear Mr Charles,

Today, we learnt about driving force, energy and power. After yesterday's Math study hall, I took many lessons from it.

For today's math problem, we did a question on Hong and her bicycle. I was able to draw the free body diagram with much less difficulty compared to last time and was able to understand the question.

One thing that I have to be careful is when doing the ΔKE equation: $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = \Sigma F \times d$. I need to read the question carefully in order to put in the correct initial and final speed values. Other than that, just make sure the positive and negative forces are correct: force in the direction of motion should be positive.

Anyway, good class today as I was able to finish the math problems today with some help and guidance from [illegible] and yourself.



1 October 2024

Using substitution to integrate

Basically

Use differential as "variables" to substitute

$\int 4x\sqrt{2x+1}\,dx$ $u = 2x+1$, $\frac{du}{dx} = 2$

$= \int 4x\sqrt{2x+1}\left(\frac{1}{2}du\right)$ (direct) $du = 2\,dx$ or $dx = \frac{1}{2}du$

OR

$= \int 2x\sqrt{2x+1}\,du$ ($2(2)\,dx = 2du$ indirect)

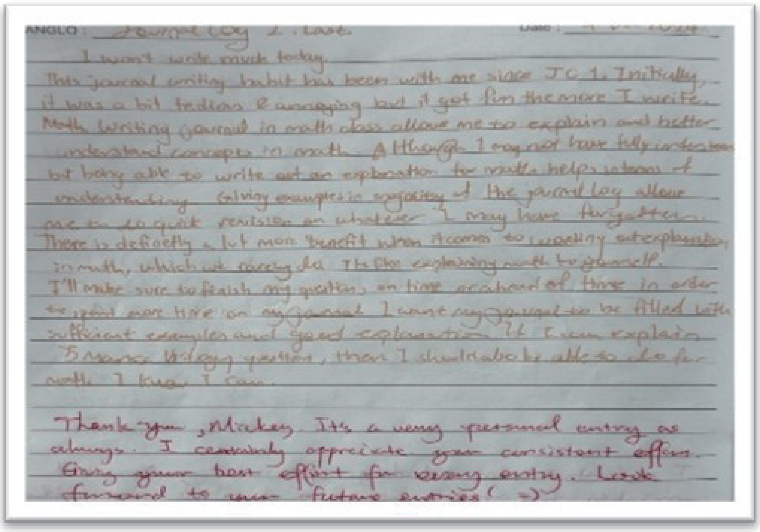
This method allows us to solve complicated integrations, but it's difficult at first as we aren't used to using differentials as a variable.

I liked today's questions as it allowed me to understand the concept more.

Figure on the left shows an example of a written narrative where the student reflects on their learning journey and challenges.

Figure on the right presents a balanced mixture of two or more modes of communication.

Based on our sample pool, the most common mode of journal writing among junior college students was a combination of symbolic or visual elements and some written components. Journal entries involving all three modes are relatively rare.

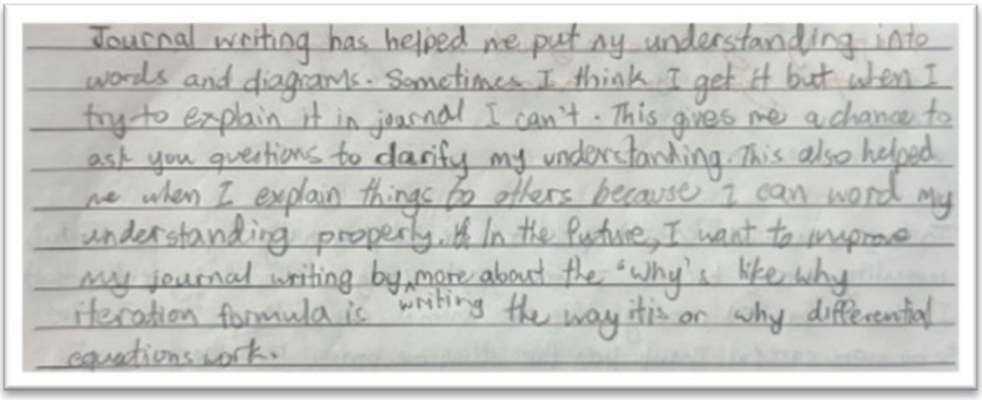


In addition to the impact on student learning, journal writing can play a vital role in fostering stronger student-teacher relationships. The journal provides a platform for individualized attention, allowing instructors to gain valuable insights into their students' thought processes, challenges, and growth areas. As highlighted in the study, journal writing can be an effective tool for promoting professional growth and development among teachers, as it encourages self-reflection and identifies areas for improvement. (Chien, 2012)

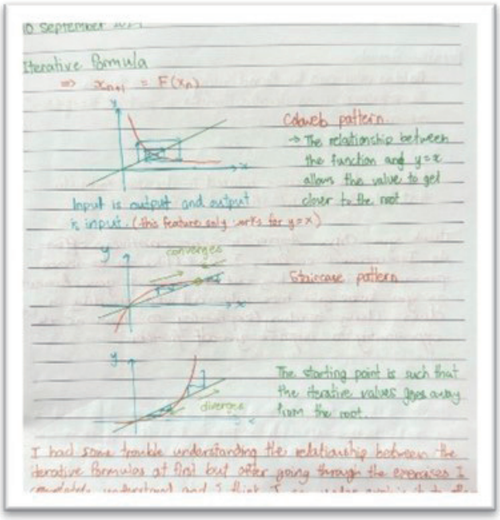
In figure on the right, it showcases the communication between the students and teachers.

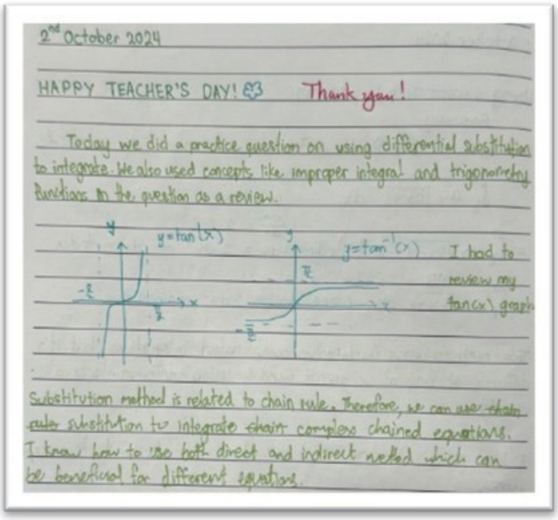
A Case Study of "Good Journals"

To further illustrate the impact of reflective journaling, we present a case study of a high-achieving student who demonstrated a strong propensity for self-reflection in their journal entries. This student's journal entries consistently exhibited a deep level of introspection, where she critically analyzed her thought processes, identified areas for improvement, and outlined strategies for addressing challenges. As a result, this student was able to develop a more comprehensive understanding of the mathematical concepts covered in the course. Her case further supports the claim on the significant impact of reflective journaling on student learning, particularly in the context of mathematical concepts. Journals produced by high-achieving students often demonstrated a strong element of self-reflection, where students critically analyzed their thought processes, challenges, and growth areas. (Morgan et al., 2014)



Journal writing has helped me put my understanding into words and diagrams. Sometimes I think I get it but when I try to explain it in journal I can't. This gives me a chance to ask you questions to clarify my understanding. This also helped me when I explain things to others because I can word my understanding properly. In the future, I want to improve my journal writing by writing more about the 'why's like why iteration formula is the way it is or why differential equations work.





The three figures above showcase examples of this student's journal entries, highlighting productive engagement with mathematical learning. These entries demonstrate a consistent reflection pattern on each lesson's core concepts. Over the past two years, this student has diligently maintained this practice, reflecting on every lesson. This sustained reflection correlates with tremendous growth in her conceptual understanding, evidenced by her high achievement in Cambridge and in-school assessments. The student's consistent reflection, as demonstrated in the journals, suggests a conscious effort to monitor and regulate her learning, contributing to her strong mathematical understanding. This case study underscores the potential of reflective journaling to foster deep learning and improve academic outcomes, particularly in mathematics. Furthermore, the student's use of diverse modalities within her journal entries, combining symbolic representations, visual aids, and written narratives, likely contributes to a more robust and nuanced understanding of the mathematical concepts (Morgan et al., 2014). This multimodal approach allows her to explore and express her understanding in ways that cater to her learning style and preferences.

Conclusion

It was seen that students who were more reflective was able to understand mathematical concepts more deeply. Even those who wrote journals simply because it was a requirement benefited from having that routine. It is thus recommended that journal prompts that promotes reflective pieces should be used more often. Journal writing also helps develop student-teacher relation. The journal provides a platform for individualised attention for all students.

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PP2-07

DEVELOPMENT OF A PROGRAMMING LEARNING ENVIRONMENT THAT INDUCES DIALOGUE WITH THE COMPUTER

Shigeki Kitajima
Meisei University, Japan, shigeki.kitajima@meisei-u.ac.jp

Keywords: Programming Learning Environment, Free-Energy Principle, Active Inference, Mathematical programming quiz

Introduction

In the programming learning environment in this study, students learn programming and acquire programming languages autonomously using programming exercises along with teaching materials and support systems that are designed to enable them to interact with computers and other learners (Kitajima, 2022). This approach relies largely on the interactivity and reproducibility of the compilers and interpreters provided with computers, enabling students to acquire knowledge using investigative activities to identify the source code and justify it. In other words, the basis of this learning environment is inducing a dialogue between students and computers, which would help the students learn programming.

The development of this programming learning environment is theoretically grounded in the free-energy principle. "Free energy" refers to a concept developed by Helmholtz, referring to the energy freely used by humans in a given system (Friston et at., 2006). The free energy principle considers the brain as a predictor of all sensations that makes Bayesian optimal inferences about the state of its external and internal environments in relation to sensory signals input through learning. It is also recognized as the free-energy minimization principle; in particular, for a self-organizing system to be in a parallel state with reference to its environment, the minimization of the system's free-energy is a necessary condition for the system to continue existing given its natural tendency toward disorder (Friston, 2010).

Within the framework of the free energy principle, the agent combines perceptual inference—used to change a current guess—and active inference—changing the sensory input through action—to minimize the free energy calculated from the generative model and the current guess in relation to the environment. To reduce the free-energy, the current guess is changed to match the generative model, and when it matches the correct recognition, it reaches the minimum (zero). Thus, the agent in the free energy principle participates in an active process that includes active inference, and recognizing this process in developing a programming learning environment based on the free energy principle (Kitajima et al., 2025).

The programming learning environment in this study is provided online to allow students to progress with their programming exercises when convenient for them. As the teacher does not provide direct instruction concerning programming or learning methods inside or outside of the classroom, the students must learn autonomously. To clarify the efficacy of this learning environment, this study investigates whether students are able to learn programming and acquire programming languages autonomously.

Research Method

Various data logs collected during the course are analyzed to determine whether students can acquire programming languages in this environment. For data with missing values, multiple imputations are first used to complete the missing values, followed by summation, and then Bayesian estimation with the semiparametric Gaussian copula model is applied to obtain estimates of the partial correlation coefficient and confidence intervals (Hoff, 2007).

Results

The average number of executions per student outside of class time, indicate that the number of executions was maintained in asynchronous learning. In addition, there was no evidence for an increase in the number of blind executions from the logs, indicating that the students were likely autonomously practicing programming.

For learning programming languages, the fact that no student failed to score shows that the students were generally able to solve and create quizzes in Python and C. At first, the quizzes primarily involved multiple-choice questions testing the students' knowledge; gradually, however, the quizzes came to more closely resemble the learning materials that the learner examines the code and runs results to make an inference about the syntax contained within them. Gradually, students also began creating programming quizzes using their mathematical knowledge and reasoning skills. In creating such quizzes, a certain level of ability to read and write code is needed, based on the programming language syntax; the same is true for answering the questions.

Conclusion

This study's objective was to clarify whether students could learn programming and acquire programming languages autonomously without being specifically taught by instructors. Through an analysis of execution logs, the study found that students could continue learning autonomously outside of class time. The students were able to master these languages, as they wrote codes while creating and solved quizzes in Python and C. Mathematical reasoning was important in this process.

In the future, the intention is to continue developing and verifying a cycle for learning programming knowledge, as well as developing a system for learning mathematics in a learning environment based on a dialogue with a computer.

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PP2-08

IDENTITIES OF STUDENTS' MATHEMATICS TEACHERS AS THE STORIES OF OTHERS

Yuriko Kimura

Graduate School of Comprehensive Human Science, University of Tsukuba Japan, s2030306@u.tsukuba.ac.jp

Keywords: gender, identity, commognition, stories about others

Introduction

There is a difference between the rates of boys and girls taking elective mathematics courses at Japanese high schools. While it has been pointed out that the sciences and engineering are seen as masculine fields, it is difficult to explain this difference in terms of a simple difference in preferences from a meritocratic perspective. It has also been suggested that girls make their choices or passively accept their position based on comparisons with others.

In recent years, in order to clarify the mechanism of girls' "mathematics avoidance", there has been an increasing focus on identity, which provides a consistent view of the cognitive and emotional experiences of mathematics learning and the social and cultural contexts of the people involved (Darragh, 2016). In particular, according to the position of the theory of *Commongnition* (Sfard, 2008), it would help to explain gender studies in mathematics more comprehensively. It is possible to capture *the stories about others* that are implicitly incorporated into the stories about the persons involved.

Therefore, the purpose of this paper is to demonstrate the applicability of the theory of identity in Commognition within gender studies in mathematics through students' narratives, the stories about others, especially about the image of mathematics teachers. This study captures and analyses the image of mathematics teachers through a questionnaire survey.

Framework

Sfard and Prusak (2005) describe identity as 'collections of stories about persons' (p. 16), and more specifically define it as 'those narratives about individuals that are reifying, endorsable, and significant' (p. 17) based on the theory of commotion. Identities can be divided into two sub-sets (Sfard & Prusak, 2005). One is 'actual identity', and the other is 'designated identity'. Actual identity is stated in the present tense and expresses events and states. Designated identity gives direction to a person's actions. If a person feels that there is a lack of consistency between the two identities and recognises that this is more important to them, they may feel unhappy.

As an individual belonging to a community, the existence of others is important for the formation of one's identity. For example, a designated identity is influenced by the existence of others, such as by borrowing the words of others or changing one's narrative in response to others, rather than being an unchanging narrative told by the individual. In addition, narratives about others and narratives told by others affect the formation of an individual's identity. In other words, there is a possibility that these stories will be incorporated into one's future or current actions through admiration, empathy, or condemnation of others (Sfard & Prusak, 2005).

Result and Discussion

This study was a pilot survey conducted between March and April 2024. The survey subjects were 214 first- and second-year junior high school students (107 boys, 97 girls, 10 no answers) at a junior high school attached to a national university, and the results were compiled using a web questionnaire. The mathematics teachers at this junior high school were two women and three men, and the head of the subject was a woman.

In response to the question 'Please tell us what you think of your maths teacher', students were asked to respond in their own words, and their answers were coded. As a result, the responses could be broadly divided into four categories: [appearance], such as 'wears glasses' and 'young person'; [characteristics], such as 'kind' and 'interesting'; [professional attitude], such as 'teaches carefully' and' lessons are easy to understand'; and [intellectual ability], such as 'clever', 'calculates quickly' and 'thinks logically'. We also received responses related to gender. Nine students (3 boys, 5 girls) mentioned the gender of their teacher, and of these, 5 students (2 boys, 2 girls) said that there were more female teachers. One student answered that they had no image of the teacher's gender.

The results indicate that students' perceptions of mathematics are closely related to their images of their teachers. In this study, it is necessary to examine how students internalize teachers' stories and compare them with themselves.

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PP2-09

INVESTIGATING THE IMPACTS AND CHALLENGES OF MATHEMATICAL MODELLING ACTIVITIES ON STUDENTS' LEARNING DEVELOPMENT

Aslipah Tasarib

The National University of Malaysia, Malaysia, p121543@siswa.ukm.edu.my

Roslinda Rosli

The National University of Malaysia, Malaysia, roslinda@ukm.edu.my

Azmin Sham Rambely

The National University of Malaysia, Malaysia, asr@ukm.edu.my

Introduction

Mathematical modelling activities have become essential in classrooms, enhancing students' learning development by fostering a deeper understanding of mathematics, problem-solving skills, and creativity (Ferri & Blum, 2019). Integrating modelling activities into educational curricula allows students to apply mathematical concepts to real-world problems, developing higher-order thinking and self-efficacy (Wang et al., 2023). However, the implementation of mathematical modelling faces challenges, as teachers must adapt to interactive, student-centered methods (Bas-Ader et al., 2023). Despite these challenges, a systematic literature review of recent studies highlights the positive impacts of mathematical modelling (Haara, 2022; Pelemeniano & Siega, 2023). This review ultimately recommends focusing on adaptive teaching strategies to cater to diverse cognitive styles, aiming to enhance students' learning development. The research questions are: i) What are the impacts of utilizing mathematical modelling on students' learning development? and ii) What challenges do students face in mathematical modelling that impact their learning development?

Methodology

In this section, a descriptive systematic review was carried out in an effort to identify an accumulation of empirical research on the issues and implications of mathematical modelling in school education. The new design of Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 proposed by Boers (2018), Mayo-Wilson et al. (2018) and Stovold et al. (2014) were used to organize and improve the review's transparency, accuracy, and quality (Page et al., 2021).

Findings

This study analyzed 24 research articles, and the results show that modelling activities have a significant impact on students' achievement and skills.

Impacts on students' learning development

From the studies, 17 themes emerged from the impacts of modelling in learning as shown in table 1.

Table 1. Impacts on students's learning development

Authors	PS	CT	IS	RS	MS	AT	DS	MR	GS	RS	MC	C	CC	SE	SiE	EM	SA
Manunure and Leung (2024)			√								√		√				
Falcó-Solsona et al. (2024)			√										√				
Pelemeniano and Siega, (2023)													√	√			
Siller et al. (2023)		√						√									
Wang et al. (2023)	√		√									√					
Chen (2022)	√	√					√						√				
Haara (2022)				√									√			√	
Holenstein et al. (2022)	√			√										√			
Xu et al. (2022)		√									√		√			√	
Lu and Huang, (2021)	√				√						√		√				
Albarracín and Gorgorió (2020)	√	√									√	√	√				√
Carreira et al. (2020)						√	√				√		√		√		
Hankeln (2020)					√								√				
Rellensmann et al. (2020)					√				√								
Greefrath (2020)							√									√	
Geiger et al. (2018)					√								√				
Krutikhina et al. (2018)	√										√						
Brown and Stillman (2017)					√						√					√	
Hagena et al. (2017)	√									√							
Tezer & Cumhur (2017)	√							√	√							√	√
Geiger (2017)		√					√						√				
Brown (2015)							√	√							√		
(Ledezma et al., 2023)	√	√				√					√	√					
(Ledezma et al., 2022)	√	√			√					√			√			√	
(Sebastia et al., 2021)	√	√	√										√			√	

PS – Problem solving skills, CT – Critical thinking skills, IS – Inquiry skills, RS – Reasoning skills, MS – Metacognitive skills, AT – Algorithmic thinking skills, DS – Digital skills, MR – mathematical representation skills, GS – geometry skills, RS – Reading skills, MC – mathematical concept, C – Creativity, CC – Communication and collaboration, SE – Self Efficacy, SiE -Simulation & experiment, EM – Engagement & motivation, SA – Social awareness

Challenges faced by students in mathematical modelling

Despite its benefits, the challenges faced by students during the mathematical modelling activities and presented as below:

1. Lack of confidence and fear of failure in mathematical abilities.
2. Limited access to resources, tools, and guidance for effective modelling practices.
3. Difficulty understand and refining real-world problems into mathematical models.
4. Confusion from the cyclical nature of modelling and problem-solving processes.
5. Misunderstandings and communication challenges during collaborative tasks.
6. Deficiencies in foundational mathematical knowledge impacting problem-solving.
7. Challenges with high-level content and complex problem-solving strategies.
8. Difficulty navigating and managing multiple steps in the modelling process.
9. Struggles with mathematical complexity, identify trends, understand data, and select models.
10. Lack of skills to validate, critique, and refine solutions in mathematical tasks.
11. Overwhelm in representing findings, decisions, and real-world implications.
12. Lack of prior experience and guidance in modelling tasks and problem-solving.
13. Reading comprehension and language barriers in understanding task instructions.
14. Examination-oriented teaching hinder critical thinking and mastering mathematical concepts.
15. Difficulty using digital tools and technology for modelling and problem-solving tasks.

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PP2-10

FROM RULES TO ONTOLOGIES: EVOLVING APPROACHES TO GENERATIVE MULTI-STAGE ASSESSMENT

Jin Min Chung
University of Iowa, United States, jinmin-chung@uiowa.edu

Sungyeun Kim
Incheon National University, Republic of Korea, syk@inu.ac.kr

Introduction

In recent years, the intersection of large-scale adaptive testing and generative artificial intelligence (AI) has garnered increased attention. Traditional multi-stage testing (MST) designs typically rely on a structured approach where test forms or modules are assembled in advance, targeting various ability levels and progressing in fixed steps. While MST has proven effective for summative assessments, it is often less flexible for on-the-fly adaptation or in-depth diagnostic feedback.

To address these challenges, Generative AI-based Multi-Stage Assessment (GAMSA) has been proposed as a next-generation framework. GAMSA leverages generative AI techniques to create, score, and report test items dynamically, potentially enabling more formative, personalized assessment experiences. Within GAMSA, three primary item-generation approaches are under examination:

Rule-Based Generation (RBG)

Language-Model Only Generation (LOG)

Ontology Model-Centered Generation (OMG)

Each approach offers a distinct blend of transparency, adaptability, and scalability, which can be crucial factors when designing adaptive assessments for diverse educational contexts. This poster will present a comparative exploration of these three methods and showcase how GAMSA can enhance both efficiency and instructional value in testing.

Core Approaches in GAMSA

Rule-Based Generation (RBG) GAMSA

RBG relies on predefined rules and templates to generate and adapt modules. Because these rules are explicitly encoded by content experts, RBG ensures high transparency and consistency. This is particularly beneficial for high-stakes examinations where explainability is crucial. However, the rigidity of RBG can limit real-time adaptability. Covering all possible learner scenarios often requires substantial manual effort, and frequent updates to the rule set may be necessary when content evolves.

Language Model Only (LOG) GAMSA

In contrast, LOG (Choi, 2024) employs large language models (LLMs; Brown et al., 2020; Kojima et al., 2022; Vaswani et al., 2017) to dynamically generate items, structure testlets, and adapt difficulty in real time. Because the model draws on vast training data, LOG can rapidly produce diverse items that align with a student's performance level. Yet this power comes with potential risks: interpretability is often opaque, and the model may carry biases from its training corpus. Additional oversight is needed to ensure fairness and curricular alignment.

Ontology-Model Centered Generation (OMG) GAMSA

OMG (Choi, 2024) combines a structured ontology—defining concepts and relationships relevant to the domain—with an LLM's adaptive generation. Templates and ontologies guide the overall item design, while the LLM supplies contextual richness. This hybrid approach balances the reliability of RBG with the flexibility of LOG. Still, building and maintaining a robust ontology demands specialized expertise and ongoing revision as subject areas expand or shift.

Comparison and Outlook

In comparing Rule-Based Generation (RBG), Language Model Only Generation (LOG), and Ontology-Model Centered Generation (OMG) within GAMSA, a few distinctions emerge. Transparency vs. Adaptivity highlights how RBG offers clarity but limited flexibility, LOG provides high adaptability but risks interpretability issues, and OMG balances both by using ontologies to guide AI outputs. Regarding Scalability and Bias, LOG can rapidly produce diverse items but may carry biases from its training data, while OMG mitigates this risk by anchoring generation in a structured ontology; RBG remains predictable yet cumbersome to expand. All three methods run on the CAFA platform (Choi, J., Kim, S., & Yoon, K., 2004), enabling streamlined data management and security. As MST evolves, educators will likely mix these strategies, refining ontology-based systems and enhancing bias control in AI-driven methods to achieve both high personalization and reliability in large-scale assessments.

PP2-11

INVESTIGATING NOVICE MIDDLE SCHOOL MATHEMATICS TEACHERS' NOTICING SKILLS IN VIRTUAL TEACHING SIMULATION USING EYE-TRACKING TECHNOLOGY

Yung-Chi Lin
National Tsing Hua University, Taiwan, yc.lin@mx.nthu.edu.tw

Introduction

Developing novice mathematics teachers' teaching skills is a challenging task. Recently, practice-based teacher education has emerged as a key approach for novice teachers' professional development (Howell & Mikeska, 2021). This approach emphasizes the importance of teachers learning in authentic classroom settings and developing high-quality teaching skills that enhance students' mathematics learning (Ball & Forzani, 2009). With advancements in technology, researchers have identified digital simulated teaching environments as effective tools for achieving the goals of practice-based teacher education. These technologies allow novice teachers to repeatedly practice teaching a small group of virtual students in a safe, controlled, and easily accessible simulated classroom environment. More importantly, digital teaching simulations provide simplified teaching situations that can be customized according to teacher educators' training objectives.

Teacher noticing refers to the ability to attend to critical events in a complex classroom setting and make appropriate decisions based on reasoning about these observed events (van Es & Sherin, 2021). This skill has been recognized as essential for effective teaching. However, developing teacher noticing is challenging, as it depends on the design of teaching tasks and the specific features of teaching situations. Recent research suggests that virtual teaching simulations can serve as valuable tools for enhancing teacher noticing (Lin, 2024a, 2024b). However, little is known about the process of developing noticing skills within virtual teaching simulations.

The purpose of this study was to investigate the development of novice teachers' noticing skills in a virtual teaching simulation environment, CartoonClass (Lin, 2024a, 2024b). Specifically, we employed an eye-tracking method to examine teachers' attention, which is a fundamental component of teacher noticing. Researchers have suggested that teachers' attentional focus in noticing can be best captured using eye-tracking technology (Wyss et al., 2021).

Methods

Participants

Nine novice middle school (7th to 9th grade) mathematics teachers (4 females, 5 males) participated in this study. They were enrolled in a mathematics education master's program at a university in Taiwan and had little to no teaching experience. The average teaching experience was 1.3 years, ranging from 0 to 3 years. According to Berliner (2004), teachers with fewer than three years of experience are classified as novice teachers.

Equipment and Procedure

Participants wore Pupil Invisible mobile eye-tracking glasses (Tonsen et al., 2020) during the teaching simulation. The Pupil Invisible glasses were equipped with two infrared cameras to record eye movements and a scene camera to capture a field view (30Hz, 1080x1080 pixels). All participants conducted a scenario-based teaching simulation using the virtual classroom simulator, CartoonClass (Lin, 2024a, 2024b, https://youtu.be/KLmb1TgzZ7c). Before the teaching simulation, they were given a handout describing the teaching objectives, prior student knowledge, and the topics to be covered in the simulation. Participants were provided with three problems related to solving quadratic equations and were asked to teach these problems to three virtual students during the simulation. The virtual students were set to perform at different achievement levels: high, average, and low. Participants had 10 minutes to prepare and 30 minutes to conduct their teaching simulation. Afterward, they were required to write reflections on their teaching experience.

Results

Overall, participants exhibited the highest proportion of fixation duration on Teaching-related elements (i.e., noticing teaching materials, such as writing on the whiteboard or reading the handout with given problems and notes), followed by Student Thinking (i.e., noticing students' mini-whiteboards), and Student Facial Expressions. The respective percentages were 46.9% (Teaching), 37.1% (Student Thinking), and 12.7% (Student Facial Expressions). Further analysis of fixation duration on Student Thinking revealed that participants focused more on the low-achiever (16.7%), followed by the average-achiever (11.9%) and high-achiever (8.5%). Regarding teaching experience, participants with more than one year of teaching experience (n=3) allocated a greater proportion of their fixation duration to Student Thinking (53.5%) compared to those with less than one year of experience (28.8%). In contrast, participants with less than one year of experience focused more on Teaching (50.0% vs. 40.5%).

Conclusion

Previous research highlighted the importance of noticing student thinking. However, our findings suggested that novice teachers primarily focused on their own instructional actions (i.e., Teaching). This tendency may be due to their inexperience and underdeveloped noticing skills. Additionally, we observed that participants with slightly more teaching experience (more than one year) exhibited better noticing skills. This finding aligns with previous studies suggesting that teachers with more experience demonstrate enhanced noticing abilities (Stahnke & Blömeke, 2021). These results provide valuable insights into what novice teachers focus on during virtual teaching simulations. They also offer meaningful implications for teacher educators aiming to use virtual teaching simulations to enhance novice teachers' professional development.

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PP2-12

DEVELOPING AN FNIRS ASSESSMENT TOOL FOR STUDENTS' FRACTIONAL STRUCTURE BASED ON APOS THEORY

Doyeon Ahn

Korea National University of Education, Republic of Korea, ahndy91@gmail.com

Kwang-Ho Lee

Korea National University of Education, Republic of Korea, paransol@knue.ac.kr

This study aimed to develop an assessment tool to measure students' ***fractional structure*** *based on APOS theory. In particular, the tool was designed to assess the cognitive development involved in the transition from the partitive unit fraction scheme to the partitive fraction scheme, as conceptualized by Norton and Wilkins (2009). Drawing on APOS theory (Arnon et al., 2014; Nagle, Martínez-Planell, & Moore-Russo, 2019), the tool was aligned with four stages of cognitive development — Action, Process, Object, and Schema.The tool was reviewed in three iterative rounds by a panel of five experts, including mathematics educators and researchers, and refined through pilot testing. A total of 30 sixth-grade students in Korea participated in the pilot study. Their responses demonstrated diverse levels of* ***fractional structure****, reflecting various APOS stages. Discussions with experts identified key indicators for distinguishing among stages. The findings offer insights into students' conceptual understanding of fractions and support the development of structured, theoretically grounded assessment tools.*

Keywords:APOS Theory, Partitive Unit Fraction Scheme, Partitive Fraction Scheme

Introduction

Understanding students' **fractional structure** is essential for designing effective instruction in mathematics education. Although many students perform symbolic operations with fractions, they often lack deep conceptual understanding (Dehaene, 1999). Norton and Wilkins (2009) proposed a developmental model involving the *partitive unit fraction scheme* and the *partitive fraction scheme*, representing key shifts in students' reasoning about fractional quantities.

To assess the shift, this study employed APOS theory as a cognitive framework (Arnon et al., 2014). APOS theory explains how students construct mathematical concepts through progressively structured mental actions and transformations—Action, Process, Object, and Schema. Recent studies have successfully applied APOS to various mathematical topics, such as slope understanding (Nagle et al., 2019), supporting its relevance across contexts.

Research Objectives

The purpose of this study is to develop an assessment tool based on APOS theory that can measure the fractional understanding structure among sixth-grade elementary students. In particular, the study focuses on analyzing students' cognitive transition from the *partitive unit fraction scheme* to the *partitive fraction scheme*, as proposed by Norton and Wilkins (2009).

Students' responses were interpreted through the lens of APOS theory—specifically the stages of Action, Process, Object, and Schema—to examine the alignment between theoretical structures and actual student reasoning. The validity and reliability of the tasks were reviewed through multiple rounds of expert evaluation and pilot testing. Furthermore, the study aims to identify the characteristic responses associated with each APOS stage, providing meaningful insights for designing instructional approaches and intervention strategies for students who struggle with fractional concepts.

Methodology

Eight tasks were developed to reflect key concepts in fractional reasoning, such as iterating unit fractions, constructing non-unit fractions, and reasoning with partitions and composed quantities. Each task was aligned with a specific APOS stage. The task design process was guided by Gaisman and Oktaç's (2019) recommendations for constructing APOS-based learning tasks.

Five experts, including in-service teachers and university-based mathematics educators, reviewed the tasks in three rounds. Between rounds, pilot testing was conducted with 30 Korean sixth-grade students. Student responses were analyzed qualitatively to identify cognitive patterns aligned with APOS theory and to refine task clarity and structure.

Results and Implications

The final set of tasks effectively elicited a range of responses representing distinct APOS stages. Some students demonstrated reasoning limited to Action (e.g., executing procedures without reflection), while others engaged in Process and Object stages, coordinating mental actions and conceptualizing fractions as mathematical objects.

Students operating within the *partitive unit fraction scheme* were often able to iterate unit fractions but struggled to construct non-unit fractions independently. In contrast, students who had developed the *partitive fraction scheme* flexibly coordinated partitioning and iterating operations, showing more advanced **fractional structure**.

Expert analyses also identified linguistic expressions and visual representations (e.g., number lines, area models) as key indicators of students' developmental stages. These findings align with Norton and Wilkins' (2009) model and demonstrate the value of APOS theory for designing tools that diagnose and support students' conceptual growth in fractions.

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PP2-13

COMPARATIVE STUDY OF THE PERSPECTIVES AND ACCEPTANCE OF UNIVERSITY STUDENTS WITH DIFFERENT EXPOSURES TO GENERATIVE ARTIFICIAL INTELLIGENCE

Ka Man Wong
The University of Hong Kong, China, u3583499@connect.hku.hk

Ming Fai Chung
The University of Hong Kong, China, chungmf@connect.hku.hk

Rachel Ka Wai Lui
The University of Hong Kong, China, lui2012@hku.hk

Introduction

The rapid advancement of Generative Artificial Intelligence (GenAI) has the potential to revolutionize various sectors, including education. GenAI, which leverages machine learning and deep learning techniques to generate new data, offers promising applications in personalized learning, student engagement, and academic success. As educational institutions strive to prepare students for a technology-driven future, understanding how students perceive and accept GenAI tools becomes increasingly important. This study investigates the impact of varying levels of exposure to Generative AI on university students' acceptance and perceived usefulness of these tools.

Literature Review

GenAI is defined as "a form of artificial intelligence that utilises machine learning and deep learning techniques to generate new data" (Yu & Guo, 2023). Its application in education is particularly promising, as it can enhance and optimize teaching methods and learning experiences (Sánchez-Prieto et al., 2020). Research by Yilmaz et al. (2023) indicates that students' acceptance of AI tools such as ChatGPT varies across different demographic groups, including gender and academic discipline. These findings suggest that students from various disciplines may have varied needs, interests, and technical capabilities.

Research Gap and Objectives

Research is needed to understand how varying levels of exposure to GenAI influence students' attitudes and acceptance. This study aims to fill this gap by investigating the perspectives of students enrolled in four undergraduate courses at a research-based university in Hong Kong, each with varying degrees of GenAI integration. Our research questions are:

"How do students' exposure to Generative Artificial Intelligence (GenAI) influence their perspectives and acceptance of GenAI?" and

"How do first-year university students in data-science / AI-related courses perceive the usefulness of GenAI for learning?"

By exploring these dynamics, this study contributes to the growing field of AI in higher education by providing insights into how GenAI's unique capabilities can be effectively integrated into academic curricula. This research aims to enhance the efficacy of GenAI implementation in higher education, ultimately preparing students for success in an increasingly technology-driven world.

Methodology

To gather insights on students' perspectives towards GenAI, a survey was conducted across four undergraduate courses: STAT1016, STAT1018, SCNC1111, and CCST5068. They were delivered during the semester from January to May 2024. Although these courses all fall under the STEM category, they have varying course objectives and course content, and are offered to different student groups. In this section, these courses are examined in detail. These courses were selected for their varying degrees of GenAI integration, providing a diverse sample for the study. The survey questions were devised with reference to the Technology Acceptance Model (TAM), which posits that perceived usefulness and perceived ease of use are critical determinants of technology acceptance (Davis, 1989). The courses were delivered between January and May 2024. In total, 380 students responded to the survey.

Discussion and Findings

Students generally have a positive view of GenAI, recognizing its usefulness in brainstorming, idea generation, and communication. However, this study underscores the significant impact of exposure to GenAI on university students' acceptance and perceived usefulness of these tools. Courses with higher GenAI exposure, like STAT1016 and CCST5068, saw greater acceptance and perceived usefulness of GenAI. Conversely, SCNC1111 students, with less exposure, showed lower acceptance. Additionally, academic background plays a crucial role, as students from empirical and quantitative disciplines may be more cautious about adopting new AI technologies. These findings highlight the need for educational institutions to integrate GenAI into curricula across various disciplines, blending theoretical knowledge with practical applications to enhance students' technical competencies and prepare them for a rapidly evolving technological landscape.

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PP2-14

TEACHERS' BELIEFS ON MATHEMATICAL PROBLEM - SOLVING WIHTIN PROJECT-BASED LEARNING

Yixuan Liu
Central China Normal University, China, yxliuccnu@ccnu.edu.cn

Yiming Cao
Beijing Normal University, China, caoym@bnu.edu.cn

Keywords: teachers' beliefs, mathematical problem-solving, project-based learning

Introduction

In the latest reform of the mathematics curriculum in China, project-based learning (PjBL) has been introduced into the primary and secondary mathematics curriculum. Mathematical problem-solving (MPS) should be taught at every grade and in every topic (Lester & Cai, 2016), while as one of the key activities within the PjBL, MPS required more creativity and application in the latest curriculum standard (MOE, 2022). Nevertheless, teachers' beliefs toward the change are critical to the success or failure (Handal & Herrington, 2003). Therefore, we pose the research question: What are teachers' beliefs on MPS within PjBL?

Method

In this paper, a purposive sampling method was used to select 14 in-service mathematics teachers who already had experience in project-based learning. Individual interviews focused on asking teachers' perspectives on MPS within PjBL and also invited them to explain their perspectives. The descriptions of different views of teaching MPS were given to teachers (Safrudiannur, & Rott, 2021). A *constant comparative method* is adapted in data analysis for categorisation of teachers' beliefs (Glaser, 1965).

Findings and Discussion

Student-centered perspective

In the current research, most of participating teachers agreed that MPS within PjBL is beneficial to students in mathematics application (9 in 14), learning interest (9 in 14), learning motivation (8 in 14), and creativity (5 in 14). Most of them also consider the MPS within PjBL as an important supplement to the mathematics curriculum.

Teachers' roles as 'guides' and 'facilitators'

Most of the participating teachers claimed their roles as guides (9 in 14), guiding students to solve the problem according to the fixed methods and ideas. Half of the participating teachers claimed their roles as facilitators (7 in 14), providing help when students encountered difficulties. The role of 'guides' is similar to the *explainer* described by Ernest (1989), and the role of 'facilitators' is similar to the facilitators described by Ernest (1989).

Highlight students' exploration and conceptual understanding

Over half of participating teachers (9 in 14) agreed with the *learner-interaction* view (Safrudiannur, & Rott, 2021), where a teacher gives students just enough information to be able to create solution methods on their own. Less than half of participating teachers (5 in 14) agreed with the *content-understanding* view (Safrudiannur, & Rott, 2021), where a teacher models one or more solution methods, allows students to choose a method, and offers suggestions when they face an impasse. Only 2 participating teachers agreed with the *content-performance* view (Safrudiannur, & Rott, 2021), where a teacher directs students toward a proposed method they are expected to follow in solving a problem.

Conclusions

The findings illustrated that teachers' beliefs on MPS within PjBL are very different from their beliefs on MPS within daily classrooms. Such findings may be beneficial for adding affordance of MPS by PjBL activities.

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PP2-15

COMPARING THE MATHEMATICAL CREATIVITY OF JUNIOR HIGH SCHOOL STUDENTS IN TAIWAN ACROSS TWO REAL-WORLD CONTEXTS

Lan-Ting Wu
National Taiwan Normal University, Taiwan, bluestop727@hotmail.com

Feng-Jui Hsieh
National Taiwan Normal University, Taiwan, hsiehfj@math.ntnu.edu.tw

Yuan-Jung Wu
National Taiwan Normal University, Taiwan, jongmath@gmail.com

Findings and Discussion

In the 21st century, globalization, automation, and big data-driven artificial intelligence have reshaped the workforce, increasing the demand for adaptable and creative problem-solving skills. In response to this trend, creativity has been considered an essential element of 21st-century skills (OECD, 2023; Partnership for 21st Century Skills, 2012).

While creativity was traditionally viewed as an innate trait possessed only by gifted individuals (Krutetskii, 1976), contemporary perspectives have shifted towards viewing it as a fundamental skill that can and should be cultivated in all students (Sternberg, Kaufman, & Grigorenko, 2008). Mathematical creativity is often assessed through three key indicators: fluency (the total number of acceptable responses), flexibility (the variety of response patterns), and originality (the rarity of response patterns) (Leikin, 2009; Haylock, 1987; Hsieh, Wu, & Wu, 2024; Wu & Hsieh, 2024).

Recognizing the growing importance of creativity in mathematical literacy, PISA 2022 incorporated creativity into its assessment framework (OECD, 2018). The framework highlighted that creativity is inherently embedded within mathematical processes. Although PISA adopted this perspective, it did not separately consider the assessment of creativity when designing test items for individual mathematical processes, nor did it independently extract and analyze students' creativity performance during problem-solving. Hsieh et al. (2024) took a novel approach by formulating test items specifically for the three mathematical processes defined by PISA, formulate, employ, and interpret, to examine students' creativity in each process separately. Their study found that students exhibited varying levels of creativity across these three problem-solving processes. The study by Hsieh et al. expanded the scope of research on mathematical creativity while also demonstrating the potential and value of assessing mathematical creativity within individual mathematical processes.

Building on these perspectives, this study aims to explore and compare students' mathematical creativity across different real-world problem-solving contexts within the three mathematical processes. This report focuses on analyzing the differences in students' creative thinking outcomes during the employ process across two contextual tasks, providing deeper insights into their performance characteristics and variations.

Methodology

We adopted the framework of Hsieh et al. (2024) and used the same constructs and definitions as those indicators in Leikin's (2009) framework. This study explores students' mathematical creativity through four real-world contexts, each represented by a carefully designed task. In this report, we compare students' creativity performance across two different real-world contexts. Given space constraints, we focus on the "employ" process within two tasks: "Guessing-Key Game" (G-Task), which involves working with algebraic operations, and "Sales and Profit" (S-Task), which involves redefinition and reclassification in a real-world context. Each task consisted of open-ended questions that students typically do not encounter in regular classroom settings, designed to measure all indicators of creativity in mathematical processes. To facilitate a more detailed analysis, we further categorized fluency, flexibility, and originality into three levels: low, medium, and high. A pilot study was conducted, followed by focus group discussions to refine the final research instrument.

In the G-Task, students play a game where they guess real keys based on public keys, transformed through a 'black-box action.' The winner is the one who designs the hardest-to-guess transformation. In the S-Task, students analyze six days of sales data from Stores A and B, using given break-even sales and net income formulas to determine Store A's net income. The indicators of creativity was assessed through structured prompts requiring diverse and unique responses. In both tasks, students were first asked to provide two highly diverse answers, then to give one uniquely original response.

This study adopted purposive sampling. The participants in both tasks were from the same four schools, 8th-grade students were randomly assigned to answer different test item., with 222 students answered the "G-Task" and 229 answered the "S-Task". Two independent raters assessed the responses, and inter-rater reliability was measured using Cohen's kappa ($k \geq 0.891$), indicating a high level of agreement.

Results

Due to space constraints, this report presents only a portion of the results related to the employ process. Additional findings will be shared at the conference. The two key conclusions from this study are as follows: (1) In terms of the proportion of students demonstrating creative thinking abilities, the G-Task outperformed the S-Task in both fluency and flexibility. However, in originality, the S-Task had a higher proportion of students than the G-Task. (2) In the G-Task, students with medium fluency performed the highest, followed by those with high fluency, while those with low fluency performed the lowest. In the S-Task, the low fluency group had the fewest students, while the medium and high fluency groups were nearly equal, indicating a more balanced distribution.

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PP2-16

SEVENTH GRADE ALGEBRAIC WORD PROBLEMS FROM THE PERSPECTIVE OF MATHEMATICAL MODELING

Alvin Chan
Good Hope School, Hong Kong SAR, chav@ghs.edu.hk

Introduction

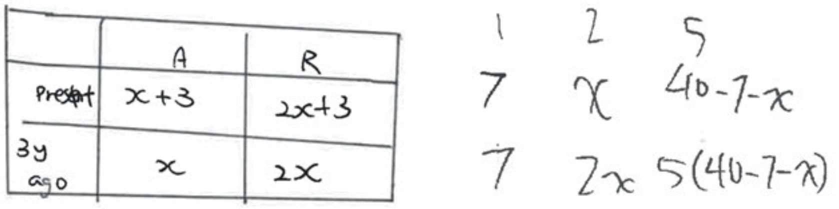
Under the curriculum guide provided by the Education Bureau of Hong Kong SAR, students are expected to "formulate linear equations in one unknown from a problem situation". However, from the author's previous teaching experience, seventh grade (age 12 to 13) students often do not perform well when solving Algebraic Word Problems (AWPs). Relatedly, according to the TIMSS Report in 2019, the international average of students successfully solving AWPs is only 26% (Mullis et al., 2020). Despite the extensive efforts made by mathematics teachers worldwide, the majority of seventh grade students have difficulties handling various levels of AWPs. Research suggests that due to their familiarity with "arithmetic-bound thinking", students find the process of setting up equations to be a huge obstacle (Steve & MacGregor, 2000). Meanwhile, Llinares and Roig (2008) argue that the process of setting up equations involves the process of mathematical modeling.

This study aims to contribute to improving the teaching and learning of AWPs by investigating ways to support students in working with AWPs through a modeling approach. Specifically, it investigates students' thinking and learning processes in the mathematics classroom, where the context is solving AWPs using linear equations. This study addresses the following questions:

- How do seventh grade students perform in solving AWPs with linear equations through a mathematical modeling approach?
- What are some potential benefits and obstacles for teaching seventh grade students to solve AWPs through a mathematical modeling approach?

Methodology: Tabular Method from a Mathematical Modeling Perspective

To cope with students' arithmetic-bound thinking, a routine is adopted to identify the variables involved and set up the equation based on the problem scenario (Lucenta & Kelemanik, 2022). Technical vocabulary (such as mathematical terms like *perimeter*, *congruent*, etc.) and verb-preposition collocations are also emphasized during the teaching to guide students into thinking on the *relationships between quantities*. Finally, a tabular method is used to help students summarize the key ideas provided (regardless of explicit or implicit relations) in the questions and used for modeling the quantities involved in the problem (e.g. see *Figure 1*). Throughout the lessons, students' artefacts are collected, and interviews are conducted for analysis into the research questions posed. Analysis mainly focuses on students' thinking and solution processes when solving an AWP.



AWP involving age of two people AWP involving no. of coins & total value

Figure 1. Example of using Tabular Method as a tool for mathematical modeling to solve AWPs

Findings and Conclusion

In response to Question 1, by analyzing students' artefacts and the interviews, it can be observed that most students find using tabular method useful in modeling real-life situations mathematically; tabular method makes it easier for them to compare the quantities provided in the problem setting. Even after the end of this project, there is evidence of students attempting to use the tabular method to solve questions from different learning units in their summative assessments. In response to Question 2, teachers should be aware of the following obstacles that students may experience:

1. **Students' fluency in Language**: It was found that there might be a language barrier even at some of the common words such as "half a dozen", "profit", etc. Such situation worsens if the policy of "English as Medium of Instruction" is adopted for non-English native speakers. As such, teachers would need to provide guidance to those who are deficient in language fluency.

2. **Difficulties in modeling different contexts**: Some students are unable to generalize a very simple result, such as the total value of n \$5-coins is \$5n. While investigating further, it was found that students fail to observe the pattern through a series of explicit examples from their daily life. Teachers need to be mindful of students' ability and prepare any additional tools to help them.

3. **Incorrect algebraic operations in the modeling process**: Teachers would need to support how to use basic algebraic operations (such as the need to add brackets during the setting up of an equation) in the modeling process. As seventh grade students may easily perform operations incorrectly, the teaching process is suggested to include checking the equations upon modeling.

In closing, the use of tabular method as a tool for mathematical modeling was beneficial to students learning how to solve AWPs. The findings also highlight areas of concern, such as reading fluency, difficulties and errors arising from the modeling process to be addressed in mathematics instruction.

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PP2-17

LESSON PLANNING TO TEACH FOR DIVERISTY AND EQUITY

Mi-Kyung Ju
Hanyang University,South Korea, mkju11@hanyang.ac.kr

Ryoonjin Song
Hanyang University, South Korea, srj430@hanyang.ac.kr

Goals and Questions

In the 21st century, as globalization develops network of interconnections and interdependence over a broad range of social life, there is an increasing social demand that education should bring up social members with an awareness of diversity and equity. Accordingly, it is recommended that teachers should be prepared for teaching mathematics in inclusive ways. In this perspective, we analyzed the teaching plans developed by preservice mathematics teachers of a Korean teacher education institution to investigate their competences of teaching for diversity and equity. For the purpose, the analysis focuses on the questions of what are the characteristics of the preservice teachers' lesson plans to mathematics for diversity and equity, and what kind of difficulties the preservice teachers confronted in planning lessons for diversity and equity.

Theoretical Backgrounds

Educational Tasks of the Globalized Era

Globalization has double-effect on our lives. On one hand, globalization as cultural standardization can lead to alienation and fragmentation, when we neglect the mutual relationship among diverse cultural groups in the context of global proximity (Bottery, 2006; Tomlinson, 1999). On the other hand, when difference is celebrated as a starting point for mutual transformation, globalization may open a window toward diversity to extend our consciousness to overcome the constraints imposed by geography. Thus, in the era of globalization, school mathematics should be reorganized to grant recognition upon diversity and equity for the empowerment of all students to practice the new global consciousness in their personal and social life (Bishop, Tan, & Karkatsas, 2015; Greer & Mukhopadhyay, 2015).

Pedagogical Design Capacity to Teach for Diversity and Equity

When considering that teaching is a design activity (Brown, 2009) and it is of essence to enhance a teacher's pedagogical design capacity (PDC) to reform school mathematics for diversity and equity (Remillard, Herbel-Eisenmann, & Lloyd, 2009). PDC, defined as a teacher's competence to perceive and mobilize curriculum materials, is a key element of a teacher's teaching competency.

Lesson planning, which can be described as a teacher's decision about teaching and learning prior to delivering a lesson, is a key part of PDC (Gonzalez, Gomez, & Pinzon, 2020). It is shown that teachers experience difficulties when planning lessons such as difficulties in articulating learning objectives, designing tasks valid for students' needs and developing assessment consistent with learning objectives.

Research Methods

This research was conducted in an undergraduate course for preservice mathematics teachers at a teacher education institution of South Korea in the 2017 spring semester. The course introduced theories and methods to enhance the competence of teaching for diversity and equity. Lesson planning was assigned as a final project for the preservice teachers to design instructional materials to teach mathematics for diversity and equity. The lesson plans were analyzed by a four-level analytical rubric for mathematics lesson plans based on the modifications to Bank's four approaches to multicultural curriculum. The preservice teachers' reflection journals were analyzed to supplement the results of the lesson plan analysis.

Results

The analysis shows that the preservice teachers had designed lesson plans as inclusive and transformative. They introduced mathematics of diverse cultures or socially controversial issues. In addition, they adapted theories of critical mathematics education and mathematics education for social justice as the theoretical framework of their teaching plans.

On the contrary, in the design of learning activities, level 1 was the most dominant among those. This suggests that the preservice teachers focused on teaching the current school mathematics based on European academic mathematics, although they acknowledge the mathematical diversity. Level 2 was also prevalent in the planning of teaching and learning process. That is, while the preservice teachers emphasized sharing of diverse mathematical ideas, they did not extend those ideas to transformative dialogue over difference.

The analysis of the preservice teachers' reflection journal, many preservice teachers mentioned about the difficulty connecting socio-political issues to mathematical concepts. Furthermore, they were concerned whether critical approaches could disadvantage. Although they endorsed critical approach for diversity and equity, it seems that they held on to their previous beliefs about school mathematics.

Conclusion and Implications

This paper presents the analysis of the preservice teachers' mathematics teaching plans that they developed in a multicultural mathematics education course at a university teacher education institution in South Korea. The analysis shows that the preservice teachers endorsed the theories of teaching mathematics for diversity and equity. However, their teaching plans had limitations because they focused on the current school mathematics and marginalized other kind of mathematics. In reflection, they mentioned about the difficulty in developing tasks to teach mathematics for diversity and equity. This suggests that teacher education programs need to present how to reorganize school mathematics curriculum to develop tasks and participation structure for diversity and equity. Moreover, it is necessary to provide opportunity for preservice teachers to reflect upon their beliefs about school mathematics from a critical perspective.

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PP2-18

HOW DO KOREAN MIDDLE SCHOOL STUDENTS MAKE VIDEOS RELATED TO MATHEMATICS?

Eunsil Cha
NE Neungyule, Korea, hoff1130@neungyule.com

Kyungwon Lee
Seoul National University, Korea, kyungwon.lee.snu@gmail.com

Oh Nam Kwon
Seoul National University, Korea, onkwon@snu.ac.kr

This poster presentation aims to share the case of the *Mathematics Peer Tutor's Tutoring Competition* to develop students' agency related to mathematics learning. The *Mathematics Peer Tutor's Tutoring Competition* was first launched in 2024 by NE Neungyule, one of the major textbook publishers in Korea. The event was organized by the Korean Society of Mathematical Education, hosted by Future Class Network, and sponsored by NE Neungyule. Students' mathematical learning has greatly benefited from its positive impact on students' learning, which has led to favorable evaluations and the expectation that it will be held annually.

In July 2024, the *Mathematics Peer Tutor's Tutoring Competition* was announced through various social networking services and newspaper articles. The competition targeted Korean middle school students, encouraging them to select key concepts, principles, or laws from their mathematics curriculum and explain them in an appealing manner that their peers could easily understand. Participants were encouraged to connect mathematical topics with various themes such as real-life applications, music, and movies to make their explanations more interesting. Each team consisted of one supervising teacher and one to two participating students. Their task was to create and submit a video of up to five minutes on a mathematics-related topic. In the preliminary round held in September 2024, a total of 178 videos were submitted by students and teachers from 17 metropolitan and provincial offices of education in Korea. The top 10 videos with the highest scores based on expert evaluations were selected. The finalists were allowed to present their videos at the final competition, where they introduced the video production process and the content for 10 minutes. After the final competition, the rankings were determined through judging. The final competition presentations have been made publicly available on NE Neungyule's official YouTube channel.

Table 1 includes the selected top 10 videos, organized by grade level. The grade distribution is as follows: 3 videos from 7th graders, 5 from 8th graders, and 2 from 9th graders, indicating that 8th graders are the most represented while 9th graders are the least. Regarding the domain chosen by the students, geometry was selected in 7 videos, functions in 2 videos, and numbers and operations in 1 video—making geometry the most popular choice. This is likely because September, the time when the videos were submitted, is generally when geometry is taught and learned in middle school. Notably, only one team (No. 1) consisted of one student and one teacher advisor, while the remaining teams participated with two students and one teacher advisor.

Table 1. The list of the top 10 videos in the Mathematics Peer Tutor's Tutoring Competition

No.	Grade	Title	Keyword	Domain
1	Grade 7	Finding lost earphones through geometric constructions	Geometric constructions	Geometry
2	Grade 7	A hidden mathematics story in Paris	Coordinate plane	Functions
3	Grade 7	Angles: Know them or not?	Angle	Geometry
4	Grade 8	Repeating decimals and music	Repeating decimals	Numbers and Operations
5	Grade 8	Discovering the centroid through experiments	Centroid	Geometry
6	Grade 8	Exploring the Pythagorean theorem using Python	Pythagorean theorem	Geometry
7	Grade 8	Memorizing quadrilateral properties with simple diagrams	Properties of quadrilaterals	Geometry
8	Grade 8	Exploring the properties of similarity in everyday life	Similarity	Geometry
9	Grade 9	Exploring the principles of quadratic functions in archery	Quadratic functions	Functions
10	Grade 9	Which seat has a better view?	Inscribed angle	Geometry

Students' approaches to video production were classified into three categories. First, videos that apply mathematical content to real-life situations (4 videos). These videos capture the process of applying mathematical concepts, principles, or laws to situations encountered by students. Two videos investigate similarity (No. 8) or focus on the principle of inscribed angles found in classrooms (No. 10). The other two videos were inspired by watching the 2024 Paris Olympics. One video (No. 2) introduces the concept of the coordinate plane to help understand the locations of Olympic venues. The other video (No. 9) documents how students, after watching a Korean archery competition, recognized and explored the connection between the trajectory of archery arrows and the graphs of quadratic functions. Second, videos that approach the explanation of mathematical concepts in a novel way (4 videos). These videos either introduce various mathematical concepts through the creative storytelling of middle school students or present multiple math-related examples. Third, videos that convey mathematical concepts in a uniquely creative manner (2 videos). One video (No. 7) presents the properties of various quadrilaterals—covered in Grade 8 of Korea—in a visually engaging, symbolic way, while the other (No. 4) highlights the connection between mathematics and music by featuring a musical performance related to repeating decimals. Three videos utilized technological tools; the tools used were GeoGebra, Python, and an AI tool. GeoGebra was employed to illustrate graphs (No. 9), while Python (No. 6) and AI tools (No. 8) were used to explain concepts effectively.

This competition highlighted the creative and self-directed approaches taken by students in their mathematics learning. We look forward to further developing the event with even greater innovation through collaboration with relevant organizations.

PP2-19

EXPLORING INQUIRY-BASED LEARNING IN MATHEMATICS TEACHER EDUCATION

Hideyo Makishita

Yamato University, Japan, hideyo@shibaura-it.ac.jp

Keywords: Inquiry-Based Learning, Mathematics Teacher Education, Curriculum Development, Mathematics Instruction, Higher Education

Introduction

The teacher training program for mathematics educators must offer courses in algebra, geometry, analysis, probability theory, statistics, and the use of computers in mathematics education. Additionally, it must provide instruction on mathematics teaching methods.

With the recent revisions to the national curriculum guidelines, educators are now expected to foster students' proactive, interactive, and deep learning. Consequently, even in university courses covering mathematical content, designing lessons that align with these principles is essential. Developing appropriate teaching materials that support such learning approaches has become increasingly important. This poster session aims to explore curricula implemented in mathematics teacher training programs in various countries while gathering feedback on the teaching materials developed by the author. Furthermore, it examines how these materials align with and contribute to inquiry-based learning. The following is the Introduction to Mathematical Analysis course syllabus at University A. Based on this content, suggestions for developing teaching materials that foster inquiry-based learning will be made.

Syllabus of University A

As an example, the syllabus for Introduction to Mathematical Analysis is presented here. On the presentation day, syllabi for other mathematics courses will also be introduced.

Course Title: Introduction to Mathematical Analysis (Course Outline)

1. Review of Set Theory: Review definitions and theorems related to "sets" and revisit example problems through preparation and revision.
2. Concepts of Upper Bound, Lower Bound, Supremum, and Infimum: Review fundamental concepts and terminology related to "real numbers."
3. Convergence and Divergence of Sequences: Study the precise definition of "convergence of sequences" through preparation and revision.
4. Theorems Related to Sequences: Review proof techniques using the ε-n method.

5. Cauchy's Convergence Criterion: Study "Cauchy's convergence criterion" through preparation and revision.
6. Convergence and Divergence of Series: Study the rigorous definition of "convergence of series" through preparation and revision.
7. Convergence and Divergence of Series with Positive Terms: Solve specific computational problems related to series with positive terms and review their connection to the ε-n method.
8. Properties of Series with Positive Terms: Review proof techniques using the ε-n method.
9. Midterm Exam and Its Explanation: Prepare by reviewing practice problems. After the exam, revisit problems that were difficult and deepen your understanding.
10. Limits of Functions: Study the rigorous definition and meaning of function limits through preparation and revision.
11. Properties of Limits: Review how to use the ε-δ method.
12. Continuity of Functions: Study the precise definition and meaning of function continuity through preparation and revision.
13. Continuous Functions on Bounded Closed Sets: Review the difference between pointwise continuity and uniform continuity using the ε-δ method.
14. Final Exam, Explanation of Exam Problems, and Q&A

Developed Teaching Material Example: Cavalieri's Principles

For example, the author proposes a new teaching material by comparing definite integrals and Cavalieri's principle in the integration study as an inquiry-based learning approach. Cavalieri's principle emphasizes geometric intuition and serves as a classical approach to calculating the area of plane figures and the volume of solids. The proposed teaching material utilizes Cavalieri's principle to engage high school students and spark their interest in mathematical analysis. This approach will be introduced to pre-service teachers to enhance their understanding of effective mathematics instruction.

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PP2-20

PRACTICE LESSONS USING INSTRUCTIONAL VIDEOS

Mahiko Takamura

Tokyo Polytechnic University, Japan, T3711@st.kougei.ac.jp

Keywords: Instructional video, Explain Everything, Color vision deficiency, Flipped classroom

Introduction

For third-year junior high school students preparing for high school entrance exams, the third semester is a crucial period for improving their scores through past exam questions. However, even among students in advanced classes, there are variations in academic ability, understanding of problems, and approaches to solving them. This paper introduces a teaching practice implemented at a public junior high school in Tokyo.

In this practice, complex problems were selected from high school entrance exam questions, and instructional videos were created focusing on "ways of thinking" and "application of previously learned concepts" rather than just "methods of solving." Students used loaned Chromebooks to study at any time and place according to their level of understanding. This is a template for preparing papers for EARCOME 9.

Considerations for Creating Instructional Videos

The instructional videos were created using the "Explain Everything Whiteboard". This application allows for the creation of videos that can be viewed on tablet devices, supports cloud storage, and integrates with Google Classroom.

Video Production Process

1. Editing the screen settings: The background color was green to resemble a blackboard.
2. Recording: Explanations were handwritten using a stylus pen while recording.
3. Editing: The recording could be stopped and resumed freely, and audio additions and cut edits were possible.
4. Saving and sharing: Videos were exported in MP4 format and uploaded to a Google Classroom folder.

Adjustments were made to enhance visibility in the video production process, considering students with color vision deficiencies.

Criteria for Selecting Problems and Explanation Policy

The videos focused mainly on difficult past exam questions, as requested by students. Additionally, supplementary videos were created for problems that students could not understand from written explanations and shared with others.

The explanation policy emphasized presenting solutions and addressing “why this approach is taken” and “which previously learned concepts are being utilized.”

Future Challenges

While creating instructional videos requires significant time, they serve as a supplementary teaching tool for teachers and allow students to review content multiple times. Moreover, students can better organize their understanding of “what they do not understand,” leading to improved quality in face-to-face instruction the following day.

Moving forward, in order to cater to students with varying academic levels, the following improvements are necessary:

1. Shorter videos (3–5 minutes) for lower-achieving students
2. Adjusting tempo and color schemes to enhance viewing ease

Additionally, issues previously identified with flipped classrooms, such as “internet access” and “device availability,” are gradually being resolved in public junior high schools. On the other hand, maintaining “student motivation” remains a challenge, but improvements in video design can, it is believed, address this issue. Moving forward, the goal is to provide an individually optimized learning environment and expand learning opportunities.

This practice expands on the content presented at the 2024 Mathematics Education Society Conference (Osaka Conference).

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PP2-21

DEVELOPMENT AND EFFECT ANALYSIS OF AUGMENTED REALITY TOOLS FOR MATHEMATICAL MODELING

Minjung Kim
Seoul National University, South Korea, 1106155@snu.ac.kr

Sangyeon Jo
Seoul National University, South Korea, jsy701@snu.ac.kr

Yunjoo Yoo
Seoul National University, South Korea,yyoo@snu.ac.kr

Research Background

In the era of artificial intelligence, the ability to independently identify and solve problems is considered a critical competency (MOE, 2020). Mathematical modeling has gained attention as an instructional approach to foster this ability, encouraging students to recognize real-world problems and apply mathematical concepts to find solutions (Jung & Lee, 2021). Despite its significance, many students struggle with mathematical modeling, particularly in the process of simplifying real-world phenomena into mathematical models (Park, 2017).

Digital technology has been actively explored to support mathematical modeling learning (Cevikbas et al., 2023). Augmented Reality (AR), which overlays virtual objects onto the real world, provides interactive experiences that facilitate understanding complex concepts (Chang & Kye, 2007). Research has shown that AR in mathematics education supports self-directed learning, enhances engagement, and promotes problem-solving skills in real-world contexts (Kim et al., 2019). However, studies linking AR to mathematical modeling learning remain scarce.

This study develops an AR-based mathematical modeling tool and applies it to middle school education to examine its effectiveness in supporting students' understanding of the slope concept in linear functions.

Introduction to AR Tool and BCAM Principles

Based on literature review and expert validation, we established four principles for AR-based mathematical modeling learning, termed the BCAM Principles:

- Bridge Principle (B) – AR tools act as a bridge facilitating the transition between real-world problems and mathematical representations (Cahyono et al., 2020).
- Connectivity Principle (C) – AR enhances real-world relevance by providing interactive, tangible experiences, allowing students to collect real-life data seamlessly (Park & Kwon, 2023).

- Adaptivity Principle (A) – AR tools provide scaffolded, personalized feedback to support individual learning needs and facilitate learning outside the classroom (Na & Yoon, 2021).
- Motivation Principle (M) – AR fosters intrinsic motivation, engaging students actively in mathematical modeling (Kaufmann & Schmalstieg, 2002).

The AR tool was designed to support students' learning of the slope concept in linear functions through real-world problem-solving activities. The tool allows students to measure slopes of physical objects (e.g., school ramps), visualize data with overlaid grids, and engage in interactive exploration.

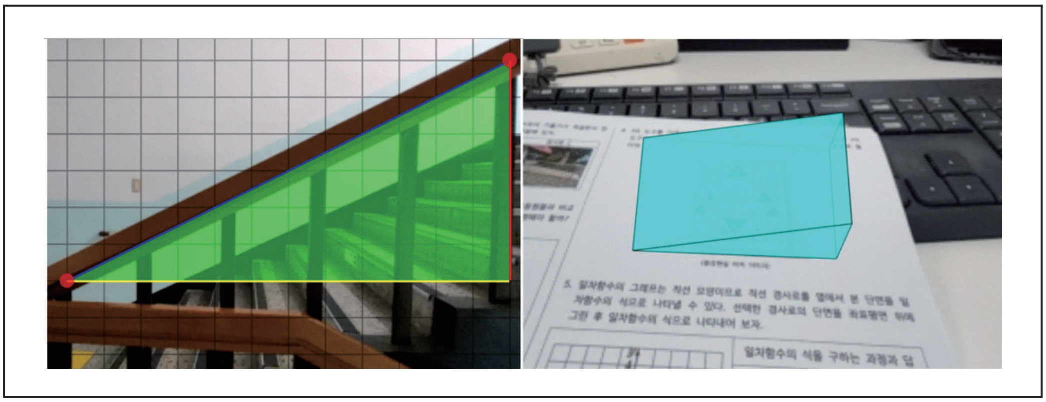

Figure 1. Examples of AR Tool Usage

Significance of the study

This study makes the following contributions:

- Integration of AR and Mathematical Modeling – By aligning AR technology with mathematical modeling pedagogy, this study demonstrates the educational potential of AR in supporting students' transition between real-world problems and mathematical representations.
- Development of AR-Based Learning Tools – The study presents a custom-designed AR tool tailored to support mathematical modeling learning, specifically focusing on the concept of slope.
- Classroom Implementation and Pedagogical Insights – The study provides real-world applications and teaching strategies, offering a framework for integrating AR into regular classroom settings.

The results indicate that students using the AR tool showed significant improvement in mathematical modeling competencies and conceptual understanding of slope. Qualitative analysis revealed that AR effectively facilitated modeling processes and enhanced students' engagement in all stages of the modeling cycle.

This study underscores the potential of AR as a pedagogical tool for mathematical modeling education and provides a foundation for further research on technology-enhanced learning environments.

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PP2-22

AN INTRODUCTION TO THE WORLD OF DATA ANALYSIS USING DATA FROM THE ENVIRONMENT

Luis Eduardo Amaya-Briceño
University of Costa Rica, Costa Rica, luis.amaya@ucr.ac.cr

We present the educational experience developed with students of the Business Informatics degree at the University of Costa Rica, Guanacaste campus. This degree does not have mathematics courses in its curriculum that prepare or introduce its students to the area of Data Analysis. For this reason, a learning project was developed, in which students collect information from Google Maps, clean it and transform it to build a consolidated table, which will be the main input to perform a PCA and a K-means, in order to characterize the country's districts by means of social, economic and religious variables. At the end of this experience, students express its usefulness, as it allows them to work on important stages of a data analysis process such as searching, cleaning, transformation and analysis.

Keywords: Data Analysis, PCA, K-means, data literacy, learning statistics.

The business informatics degree at the University of Costa Rica, in its study plan, includes a single statistics course. It has usually had a focus on basic and descriptive statistics with little application to the context. In recent years, the program coordinators have detected the importance of including multivariate data analysis topics as transversal axes in other courses of the program. This is why in the applied mathematics courses, linear algebra and numerical methods, introductory topics on data analysis have been included, within which work has been done on the teaching and application of principal component analysis (PCA, Jolliffe, 2002) and the study of classification algorithms such as K-means (Bishop, 2006).

This work seeks to carry the spirit of the above by making use of freely accessible data and tools. We use the Google Chrome plugin, ImportfromWeb (Pinauldt, 2024) to collect information on socioeconomic variables of some of the districts of Costa Rica, and with these data we build a table that will be used to carry out the PCA and K-means analyses.

An intrinsic objective of our work is to be able to contrast what our analyzes say about the groupings found by us, with respect to what government indices, such as the cantonal human development index (IDH) of Costa Rica (UNDP, 2024). This index is a synthetic measure that evaluates the country's progress in three basic dimensions: long and healthy life, knowledge, and a decent standard of living. It is based on indicators such as life expectancy at birth, literacy and school enrollment rates, and gross national income per capita.

Methodology

This experience was carried out in the first two semesters of 2023 and 2024 and involved 35 students. Each student was assigned a canton[1], which had to be the place where he or she came from.

1) Costa Rica is organized geopolitically in 7 Provinces, 84 Cantons, and 489 Districts.

If there were students from the same cantons, the teacher assigned different canton to one of the students.

The provinces of San José, Cartago, Alajuela and Heredia form the Great Metropolitan Area (GAM, from the Spanish name), which concentrates most the country's population, wealth and services, while the provinces of Guanacaste, Puntarenas and Limón are coastal provinces, with lower indices of development, wealth and services (Programa Estado de la Nación, 2020).

Table 1. Cantons and Districts in Costa Rica

Province	Cantons	Districts
San José	20	123
Alajuela	16	116
Cartago	8	51
Heredia	10	47
Puntarenas	13	61
Guanacaste	11	61
Limón	6	30
TOTAL	84	489

Figure 1. Geopolitical Division of Costa Rica

https://guiascostarica.info/territorial/atlas-cantonal/

The university campus, located in Guanacaste, has a majority of students from cantons of this province, which required to assign different, cantons outside of Guanacaste from the GAM.

Once the cantons were assigned, the students had to carry out a search for each of the districts of the assigned canton, and work with the variables: *bars, restaurants, schools, churches, hospitals, clinics, pharmacies, hospitals, shops, gyms, banks and veterinarians*.

The Google Chrome plugin, ImportfromWeb, was used to obtain this information, by asking *"hospitals of district xxx in province xxx"*. This list includes the name, location (latitude and longitude), ratings, comments, among others, of each record returned.

The column that gives the latitude and longitude is extremely important, because the plugin tends to include records that do not necessarily belong to a requested district. Each student has then to validate the information existing polygons of each district. This validation was accomplished through student developed Python or MySql; the polygons were consulted from the page https://data.humdata.org/dataset/cod-ab-cri

Once the data were collected and consolidated, each student had to count the values found for each of the variables in their respective districts. With this, a consolidated table was built that included the information collected by all the students, 117 districts which would be the input they would need for subsequent analyses. The table has a structure like the following

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Provincia	Cantón	Distritos	Código Postal	Bares	Restaurantes	Escuelas	Iglesias	Hospitales	Clinicas	Farmacias	Tiendas	Gimnasios	Bancos	Veterinarios
35	Alajuela	San Carlos	La Palmera	21009	7	17	5	1	0	0	0	0	1	0	0
36	Alajuela	San Carlos	Venado.	21010	0	4	1	1	0	0	0	0	0	0	0
37	Alajuela	San Carlos	Cutris.	21011	1	0	19	0	0	0	0	0	0	0	0
38	Alajuela	San Carlos	Monterrey.	21012	2	2	2	2	0	2	2	7	3	2	1
39	Alajuela	San Carlos	Pocosol.	21013	11	31	15	13	0	9	2	56	2	3	3
40	Alajuela	Upala	Upala	21301	8	49	30	28	4	16	6	159	5	5	1
41	Alajuela	Upala	Aguas Claras	21302	0	14	10	14	1	0	0	15	1	2	0
42	Alajuela	Upala	San José	21303	9	6	19	16	0	2	0	14	0	0	0
43	Alajuela	Upala	Bijagua	21304	4	36	14	7	0	3	2	59	2	2	2
44	Alajuela	Upala	Delicias	21305	9	3	6	14	0	1	0	14	0	0	0
45	Alajuela	Upala	Dos Ríos	21306	2	6	8	3	0	0	0	9	2	0	0
46	Alajuela	Upala	Yolillal	21307	0	4	8	3	0	2	0	2	1	0	0
47	Alajuela	Upala	Canalete	21308	1	6	7	12	1	2	0	12	1	0	0
48	Alajuela	Guatuso	San Rafael	21501	12	35	22	14	2	2	2	62	4	3	0
49	Alajuela	Guatuso	Buenavista	21502	0	4	5	2	1	0	0	6	0	0	0
50	Alajuela	Guatuso	Cote	21503	0	2	4	1	0	0	0	1	1	0	0
51	Alajuela	Guatuso	Katira	21504	4	20	8	7	0	1	2	41	1	0	0
52	Alajuela	Rio Cuarto	Rio Cuarto	21601	1	18	9	4	1	1	1	43	2	1	1
53	Alajuela	Rio Cuarto	Santa Rita	21602	0	3	2	1	0	2	1	6	0	2	1
54	Alajuela	Rio Cuarto	Santa Isabel	21603	0	1	3	1	0	0	0	0	0	0	0
55	Guanacaste	Liberia	Liberia	50101	57	155	100	85	6	47	6	142	25	13	10
56	Guanacaste	Liberia	Cañas Dulces	50102	1	7	7	7	0	1	0	6	3	0	0
57	Guanacaste	Liberia	Mayorga	50103	0	1	3	2	0	1	0	6	0	0	0
58	Guanacaste	Liberia	Nacascolo	50104	2	24	3	4	0	1	0	10	0	3	0
59	Guanacaste	Liberia	Curubandé	50105	1	9	3	2	0	1	0	5	1	0	0
60	Guanacaste	Nicoya	Nicoya	50201	37	115	50	46	2	39	15	152	18	15	9
61	Guanacaste	Nicoya	Mansión	50202	12	18	7	7	0	1	0	27	0	1	0
62	Guanacaste	Nicoya	San Antonio	50203	6	6	12	24	0	1	0	7	0	0	0
63	Guanacaste	Nicoya	Quebrada Honda	50204	2	13	10	18	0	2	0	20	0	0	0
64	Guanacaste	Nicoya	Sámara	50205	14	52	37	5	0	10	2	98	6	5	2
65	Guanacaste	Nicoya	Nosara	50206	12	92	27	6	0	11	3	61	11	3	4
66	Guanacaste	Nicoya	Belén de Nosarita	50207	7	6	19	16	0	0	0	13	4	0	0
67	Guanacaste	Santa Cruz	Santa Cruz	50301	27	58	25	23	3	24	11	161	13	25	4
68	Guanacaste	Santa Cruz	Bolson	50302	2	5	2	2	0	1	0	11	0	0	0

Figure 2. Data Collected by Districts

With the previous table, the students, in R or Python, performed principal component analysis or classification with K-means, this with the aim of trying to characterize and group them according to the variables studied.

Results

In order to determine similar districts, relationships between variables and other elements that will be interesting, students perform a PCA, having among the main results

a. Dimension reduction with two components with about 90%

b. Good representation of the majority of individuals (districts), this through the study of their square cosines.

c. Closeness in the behavior of the "poor" districts of the GAM with those of other districts of provinces outside it.

d. Nearby behaviors of the head districts of the most developed cantons of Guanacaste such as Liberia, Nicoya and Santa Cruz.

e. Regarding the variables, there is a positive correlation between variables such as the number of banks, gyms and pharmacies, which in turn contrast with the number of stores and restaurants.

In order to classify and describe the districts, the students applied a k-means algorithm.

a. With the elbow criterion it can be noted that two or three classes will be the optimal number of classes, most students opt for three classes. They themselves express being curious to study more regarding how to determine the optimal number of classes.

b. When looking at the districts that make up the three groups, it can be noted that there is a group with a large presence of districts known for their socioeconomic development, another with districts known for their enormous poverty and another group that would have those districts with intermediate socioeconomic development.

c. Students note how districts of certain cantons known for their low development are located in the same clusters as districts of more developed cantons. This shows that these types of studies need greater geopolitical depth to be prepared. For example, in the canton of Santa Cruz in Guanacaste, a canton with low socioeconomic indices, there are two districts (Cabo Velas and Tamarindo) that are located in the same group as developed districts of the GAM.

General results of the entire project

a. Observing this constant interest on the part of the students in the topic to be developed, access, cleaning and manipulation of data seems to be an extremely interesting challenge within their computational background.

b. Being able to challenge or validate their beliefs about the socioeconomic developments of certain districts based on results obtained with data and analysis tools that are free to use.

c. Losing the perception of students the they think that mathematics is not useful.

d. The project was very much enjoyed by students to the point that some of them have participated as speakers at local or Central American computing conferences, sharing parts of the project and their experience with it.

Conclusion

Although at first, upon learning about the topic and development of the project to be developed by the students, a large majority had a look of fear and doubt, as the weeks passed and the different stages of the project were implemented, those initial sensations changed. The students showed interest and enthusiasm in the development of the work, they emphasized that they were motivated by the results that could be found in the analyzes and the computational challenges they encountered when acquiring, cleaning and manipulating the data. The PCA, and k-means algorithms carried out by the students, to be a first approach by them to these topics, although they omit elements, present the main elements and considerations of these when presenting their reports; We must not forget that they are university students with very little statistical knowledge.

We consider that the objective of introducing Business Computing students to data analysis topics, using free-use tools, is achieved to a large extent, as the project allows students to experience the different stages that are usually involved in a data analysis team: data collection, cleaning, transformation, analysis and visualization; where we also do it with free data, taken from our environment and analyzed with tools of a similar nature.

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PP2-23

AN ANALYSIS OF THE CONTEXT OF PROBABILITY EDUCATION IN JAPANESE MATHEMATICS TEXTBOOKS FROM LOWER SECONDARY SCHOOL TO UPPER SECONDARY SCHOOL: WITH NEGATIVE CAPABILITY AS A BACKGROUND

Hiroto Fukuda

Okayama University of Science, Japan, hfukuda@ous.ac.jp

Kaito Sato

Okayama University of Science, Japan, s22s314tm@ous.jp

Background

As a result of climate change and the recent COVID-19 pandemic, socioecology is increasingly focused on in mathematics education research (e.g., Coles, 2017; Fukuda, 2020). Complex phenomena in today's society, such as climate change and pandemics, are extremely difficult to simplify and model, and we can only manage complex objects while maintaining their complex aspects. We can be said to have entered an era in which we must embody the paradigm of Wittmann's systemic-evolutional —method (Wittmann, 2001; Hirabayashi, 2001; Fukuda, 2016). We must reconsider the paradigm of implicit mathematics education, which claims to solve problems. When faced with a complex object that can only be handled in its complex form, it is not difficult to imagine that it cannot be solved at all. In other words, we need to drastically change the direction of mathematics education from one that assumes solutions to one that does not and quickly set sail.

Therefore, this study focuses on negative capability (NC), which was first proposed by John Keats and popularized by the psychiatrist Wilfred Bion. NC has been described in a variety of ways; for example, it has been defined as "the ability to endure situations that cannot be answered or dealt with in any way" (Hahakigi, 2017, p. 3) and "the ability to be in a state of uncertainty, wonder, and skepticism without hastily seeking proof or reasons" (ibid., p. 3). Of course, the ultimate aim is a mathematics education that does not assume problem solving; for that reason, mathematics education that does assume problem solving is a necessary condition for the ultimate goal.

An example given in Fukuda and Sato (2025) is the Tuesday Birthday Problem shown in Figure 1. From the perspective of Person A, since A naturally knows the gender of the child, the probability sought is either 0 or 1, and it can be said that the problem in Figure 1 is impossible to solve. In other words, it can be thought that the probability of the questions involving people in the context of the question may be 0 or 1. From this, confirming this possibility through textbook analysis can be said to be meaningful in considering mathematics education with a focus on NC in the future. Therefore, the purpose of this research is to verify whether there are questions involving people in the context of the question—that is, problems that are impossible to answer—using text book analysis and probability education as an example.

> Mr. A has two children. One of them is a boy born on a Tuesday. Find the probability that the other child is also a boy. Assume that the probability of a boy or a girl being born is 1/2, and that the probability of being born on any day from Sunday to Saturday is 1/7.

Figure 1. Tuesday Birthday Problem

Textbook Analysis

For textbook analysis, we used Japanese textbooks and focused on the analysis of probability content in the first and second year of junior high school and Mathematics A in high school. We analyzed all probability-related questions in the textbooks, categorized the types of contexts in these questions, and analyzed the extent to which there was a human context. The textbooks used for the analysis were all published by the same company (seven books in total) for junior high schools and one book from each of the three companies with the highest market share (three books in total) for high schools. Table 1 presents the results of the analysis. The "Other" category refers to contexts other than people, and Table 1 shows the contexts related to people.

Table 1. Types of Contexts in Probability Problems

Type of Context	Year 1 in Junior High School	Year 2 in Junior High School	Mathematics A in High School
Newborn baby	2 (10%)	0 (0%)	0 (0%)
Passenger	0 (0%)	0 (0%)	1 (1%)
Student	0 (0%)	0 (0%)	2 (1%)
Marksman	0 (0%)	0 (0%)	1 (1%)
Other	18 (90%)	180 (100%)	131 (97%)
Total	20 (100%)	180 (100%)	135 (100%)

In the context of people, the problem of the marksman in Mathematics A in high school was an impossible problem, like the example of the Tuesday Birthday Oroblem, where the probability could change depending on one's position, and in addition, it was a problem that could be solved. As the context of people was not even covered in the second year of junior high school, it can be said that there is very little context for people throughout the entire course and that there is no probability education that can cultivate NC.

Future Issues

In this paper, we focused on probability education and analyzed textbooks, but further analysis is needed to determine the situation in areas in addition to probability. Based on the results of the analysis, we considered how to provide mathematics education that can develop NC.

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PP2-24

FACTORS THAT PROMOTE STUDENTS' SENSE OF BELONGING IN DIVERSE INTRODUCTORY MATHEMATICS CLASSES

Sarah H. Park
University of Georgia, USA, spark3@uga.edu

Introduction and Background

A sense of belonging in the undergraduate mathematics classroom is crucial for student engagement, persistence, confidence, and achievement in college (Wilson et al., 2015). However, introductory mathematics courses like college algebra and precalculus often act as gatekeepers, hindering mathematics persistence (Seymour & Hunter, 2019). This study explored how students experience sense of belonging in gateway math classrooms at a diverse, minority-serving institution. Sense of belonging involves students' perceived social support and feeling of connectedness on campus. For this study, Strayhorn's (2019) definition of sense of belonging is used: "Students' perceived social support on campus, a feeling or sensation of connectedness, and the experience of mattering or feeling cared about, accepted, respected, valued by, and important to the campus community or others on campus" (p.4).

Research indicates that a sense of belonging is associated with positive outcomes such as academic achievement and mental health (Strayhorn, 2018). Conversely, a lack of belonging can lead to students leaving STEM majors, even with high academic achievement (Strayhorn, 2018; Good et al., 2012). Several factors enhance a sense of belonging, including supportive faculty, engaging pedagogies, positive peer interactions, and a welcoming campus culture (Hurtado et al., 2015; Gasman & Nguyen, 2014; Museus et al., 2017; Nguyen et al., 2021). In the classroom, belonging is linked to self-efficacy, motivation, engagement, and persistence (Freeman et al., 2007; Kirby & Thomas, 2022; Wilson et al., 2015; Zumbrunn et al., 2014). A Sense of belonging is further enhanced when students perceive their instructors as caring and supportive, and when these instructors encourage peer collaboration (Wilson et al., 2015; Kirby & Thomas, 2022). Despite its importance, research on sense of belonging remains underexplored for students in diverse settings, particularly in mathematics classrooms (Booker, 2016; Johnson, 2012; Rainey et al., 2018; Strayhorn, 2018).

Research Questions

This study was guided by the following research questions: 1. How do students' sense of belonging in college algebra and precalculus classrooms compare across different racial and gender groups? 2. How do students describe their learning environment, experiences, participation, persistence, support systems and challenges in college algebra and precalculus as they relate to their sense of belonging?

Methods

This study was conducted at a diverse, open-access, four-year public college in the Southeast with approximately 12,000 students. The student body demographics are as follows: 12% Asian/American, 32% Black, 27% Latinx, 24% White, 59% Female, and 41% Male. About 40% of freshmen are first-generation students, and over 50% are eligible for Pell grants. The college is designated as both an Asian American and Pacific Islander Serving Institution and a Hispanic Serving Institution. Typically, college algebra or precalculus is typically the first math course for STEM first-year students.

This poster presents preliminary results from a mixed-methods study using quantitative (pre- and post- sense of belonging surveys) and qualitative methods (mathematics autobiography and semi-structured interviews). In the first phase during the Fall 2023 semester, 1,135 students completed the presurvey, and 639 completed the post-survey. Descriptive statistics and multi-factor ANOVA were used to analyze sense of belonging across different racial-gender groups. In the second phase, 13 female students (two Black-Latina, five Black, and six Latina) were interviewed, with 11 completing mathematics autobiographies. Interviews were transcribed and analyzed using thematic analysis (Braun & Clarke, 2006).

Results

Quantitative results indicate that Black male students had the highest sense of belonging (4.563), while male Asian students had the lowest (4.297). Sense of belonging in these introductory mathematics courses did not significantly differ across gender or race. However, there was a statistically significant difference in belonging between students with different levels of mathematics affinity ($p<0.001$), expected final grades ($p<0.001$), and pre-belonging scores ($p<0.001$). Students who had higher pre-belonging scores, higher mathematics affinity, or higher expected final grades reported a higher sense of belonging in their mathematics classes.

Qualitative findings revealed that six factors are pivotal in positively affecting students' sense of belonging in diverse introductory mathematics classes: professor's mathematical microaffirmations, students' perception of their professor as caring and helpful, professor's encouraged peer collaboration in class, connections with class peers, high mathematics self-efficacy and perception of classroom diversity.

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