SAJSE

SOUTHEAST ASIAN JOURNAL OF STEM EDUCATION

A publication of SEAMEO STEM-ED
ISSN: 2709-1252
Vol. 4 No. 1
January 2024

Southeast Asian Journal of STEM Education

A Publication of SEAMEO STEM-ED
40 Pages
ISSN: 2709-1252

2024
Vol. 4 No. 1
January 2024

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Contents

Page

PREFACE

Welcome to the Southeast Asian Journal of STEM Education (SAJSE), a prominent online platform established by SEAMEO STEM-ED, dedicated to the advancement of STEM education in Southeast Asia. As an open-access publication, SAJSE is an invaluable repository for insights, ideas, and innovations that define the future of STEM education in the region.

At SEAMEO STEM-ED, we believe in the power of collaboration and knowledge exchange to advance STEM education. The articles in SAJSE reflect this belief, offering a wealth of quality knowledge that transcends regional boundaries. Our dedication to openness is demonstrated by our usage of Creative Commons licencing, which allows for the free use, distribution, and replication of our published content with due credit.

We are excited to announce that we are opening up opportunities for teachers and students to share their voices and reflections from the classroom. Teachers are invited to share their innovative practices, challenges, and insights in teaching STEM subjects, providing valuable perspectives that can benefit educators across Southeast Asia. Similarly, students are encouraged to share their experiences and reflections on STEM science projects, highlighting the impact of hands-on learning experiences on their education and personal development.

This initiative aims to echo the voices of teachers and students, providing a platform for them to share their unique perspectives and contribute to the broader conversation on STEM education in Southeast Asia. By amplifying these voices, we hope to inspire others and drive positive change in STEM education practices and policies.

Authors who submit their papers to SAJSE will benefit from the journal's rigorous peer-review process, ensuring the quality and integrity of published articles. Additionally, published papers will be freely accessible to educators, researchers, and policymakers, facilitating the dissemination of innovative practices and ideas in STEM education.

We invite educators, researchers, and innovators from across Southeast Asia to join us in this quest to elevate STEM education. Together, let us construct a cooperative and inclusive learning ecosystem that equips the future generation of innovators and solution seekers, propelling Southeast Asia towards a future characterised by innovation and excellence.

Thank you for being a part of this journey.

Warm regards,

SEAMEO STEM-ED

EDITORIAL

Welcome to SAJSE, the leading platform for advancing STEM education and encouraging innovation in Southeast Asia. Our journal exemplifies the spirit of collaboration, creativity, and capacity building. We are dedicated to making STEM education accessible to all, while also offering chances for educators and students to share their research, teaching techniques, and new ideas. This open-access journal serves as a beacon for researchers, educators, policymakers, and students seeking excellence in STEM education.

A Platform for Diverse Voices

The Southeast Asian Journal on STEM Education transcends its role as a mere repository of information, establishing itself as a vibrant forum that embraces a plurality of perspectives. This journal curates a comprehensive array of contributions, encompassing seminal research articles from seasoned scholars, innovative pedagogical methodologies from educators, and introspective analyses on integrated STEM disciplines authored by students. It operates as a platform that acknowledges and values the diverse viewpoints of all constituents within the educational sphere, thereby facilitating a collective ethos of learning and developmental synergy.

Bridging Policy and Practice

A distinctive feature of this journal is its specialized policy section, designed to stimulate dialogue on the development and enactment of educational policies, with a particular emphasis on STEM disciplines. This section covers a broad spectrum, from theoretical propositions to empirical research and the exchange of best practices. The journal aims to contribute to and impact policy-making processes that determine the trajectory of educational advancement. It represents an effort to reconcile policy with practice, guaranteeing that educational innovations are firmly anchored in the practical landscape and meet the requirements of learners.

Global Perspectives with a Local Focus

Although the journal invites submissions from educators, policymakers, teachers, and students globally, it prioritizes local implementations, research, or practices from Southeast Asian countries. This emphasis underscores a dedication to tackling the distinct challenges and seizing the opportunities present in the region, advocating for solutions that are informed by global perspectives yet tailored to local contexts.

A Call to Action

We warmly invite all stakeholders, particularly teachers and students, to contribute to the Southeast Asian Journal on STEM Education. Your contributions to research, practices, and reflections do more than enrich our collective knowledge; they play an active role in sculpting a future where STEM education is universally accessible, inclusive, and profoundly influential. This journal stands as a testament to the strength of collaborative effort, reinforcing the notion that every contribution, regardless of its size, is instrumental in unlocking the vast potential of STEM

the Southeast Asian Journal on STEM Education serves as a beacon, illuminating the path toward a more enlightened future via the progression of STEM education. It summons all who are dedicated to nurturing scientific thought and leveraging scientific inquiry to elevate the quality of teaching and learning. United in purpose, let us venture forth on this path of exploration and innovation, laying the foundations for future generations to build upon.

Best regards,

SAJSE Editors

POLICY

SECTION

REFLECTION FROM SOUTHEAST ASIAN REPRESENTATIVES ON THE AI GUIDANCE FOR SCHOOLS TOOLKIT

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ABSTRACT

Reflecting on the insights of Southeast Asian representatives, the impact of Generative Artificial Intelligence (AI) in education is explored, with a focus on both the challenges and opportunities of AI technology implementation. SEAMEO, through collaboration with various partners, has played a pivotal role in understanding AI's implications for education. Expert group discussions have underscored the necessity for resources, guidance, and training to aid educators in the responsible incorporation of AI into teaching practices. The potential of AI to improve academic performance and administrative tasks is emphasised, alongside addressing concerns like data privacy and the need for comprehensive teacher training. The discussion highlights the critical need for investments in teacher support, technological infrastructure, and policies that promote the ethical and effective application of AI within the educational sector.This reflection contributes valuable insights for educational institutions in Southeast Asia seeking to navigate the complexities of AI integration and prepare students for success in a technology-driven learning environment.

Keywords: Artificial Intelligence (AI) in Education, AI Policy

1. Introduction

Addressing Artificial Intelligence (AI), especially Generative AI, in educational settings is crucial in navigating the technological advancements influencing global education systems. The Southeast Asian Minister of Education Organization (SEAMEO) in collaboration with various partners have been working on understanding the impact of Generative AI in education. SEAMEO Regional Centre for STEM Education (SEAMEO STEM-ED) has formed an expert group which comprises nominated representatives from SEAMEO member countries' ministries of education. The group will meet on a regular basis to discuss resource development and share ideas on the progress of using Generative AI in education, and teaching and learning about AI, in the region. This paper is based on the expert group's discussion and provides information on the present status of employing Generative AI as well as the development of guiding resources for the Southeast Asian education community.

SEAMEO Secretariat and SEAMEO STEM-ED joined the TeachAI initiative to develop suitable resources for educators and policy makers on understanding and addressing teaching with and about AI. One of these resources, the “AI Guidance for Schools Toolkit”, is designed to help education authorities, school leaders, teachers, and others create thoughtful guidance to help their communities achieve the potential benefits of incorporating Generative AI in education while understanding and mitigating the potential risks.

The “AI Guidance for Schools Toolkit” is designed to support schools in effectively understanding how AI intersects with their curricula and administrative procedures and systems, thereby ensuring that they remain relevant and adaptive to the evolving educational landscape. The toolkit was authored by representatives from Code.org, the Consortium for School Networking, Digital Promise, the European Edtech Alliance, and Policy Analysis for California Education, who are all part of the TeachAI initiative. Earlier drafts were informed and reviewed by target audiences, the TeachAI steering committee, and the TeachAI advisory committee that includes SEAMEO, SEAMEO STEM-ED, UNICEF, and the World Bank. The Southeast Asian AI expert groupI had its first meeting to examine the creation of the toolkit and its potential benefits to the Southeast Asian education community. The toolkit is available on the TeachAI website at https://www.teachai.org.

2. Reflections on Generative AI and Education in Southeast Asia

The meeting of the Southeast Asian AI expert group was conducted as a focus group study on AI in education, with participants from SEAMEO Member Countries as well as representatives from SEAMEO STEM-ED, SEAMEO Secretariat, Code.org and the TeachAI Initiative. The meeting discussed the perception of AI and Generative AI in their respective countries, the need for resources on these issues, the importance of AI guidance in education, and perceptions on the AI Guidance for Schools Toolkit drafted by TeachAI. The results of this meeting are presented in the following parts.

2.1. Challenges in Implementing AI in Education

The integration of Artificial Intelligence (AI) in education presents both opportunities and challenges across various countries, as explored by participants in the study. One of the primary obstacles highlighted includes the scarcity of educators proficient in AI, compounded by the struggle against competing priorities within educational institutions. Despite these challenges, the potential benefits of employing AI technologies in education are significant, such as the opportunity to enhance academic performance, exemplified by improvements in math scores. It was recognised how many of these highlights resonate globally, and not only in Southeast Asia.

Singapore emerges as a pioneering case study in the realm of AI application within education. The country has taken proactive steps by introducing AI literacy programmes at the polytechnic level, demonstrating a commitment to equip its future workforce with essential AI skills. This initiative is further supported by AI Singapore, a dedicated organisation that endeavors to foster AI adoption not only in education but also across various industries, thereby strengthening the nation's AI ecosystem.

Furthermore, the Ministry of Education in Singapore has been instrumental in integrating coding and AI learning into the curriculum, aiming to cultivate a technologically proficient generation. Despite these advances, Singapore faces its own set of challenges, particularly in maintaining academic integrity. There is a growing concern that students might become overly reliant on AI tools for completing assignments, potentially undermining the genuine learning process. This situation underscores the need for a balanced approach in implementing AI in education, ensuring that technological advancements serve to enhance, rather than diminish, educational quality and student engagement. This led to the view that education may need to rethink its learning processes, especially assessment.

2.2. Benefits of AI in Education

Deploying Artificial Intelligence (AI) tools within the educational sector could offer numerous advantages, particularly in enhancing the teaching and learning experience. One significant benefit is the ability of AI to assist teachers in swiftly creating and tailoring educational content. This capability not only saves valuable time but also enables educators to address the diverse learning needs of their students more effectively, thus fostering a more inclusive learning environment.

Moreover, AI technologies may extend the boundaries of traditional classroom support by providing more students with access to a tutor and study partner. This availability may help more students to receive assistance and feedback on their learning, thereby promoting a more flexible and self-paced learning journey.

In addition to impacting teaching and learning processes, AI tools can also play a crucial role in improving administrative tasks and operational efficiency in educational institutions. Through automating routine tasks, such as scheduling, grading, and attendance tracking, AI enables schools to optimise their resources and focus more on educational quality and student support. Consequently, integrating AI in education might not only enhance pedagogical practices but also contribute to the overall efficiency and effectiveness of educational administration.

2.3. Risks of AI in Education

The expert group raised points of apprehension regarding the integration of AI tools in education particularly on academic integrity. There is fear that students might either plagiarize or become excessively dependent on AI for completing assignments and tasks, raising significant ethical and educational issues. This over-reliance on technology is also feared to erode critical thinking and problem-solving abilities among students, skills that are essential for personal and professional success in the 21st century.

Furthermore, the effectiveness of detection software, designed to identify plagiarism or inappropriate reliance on AI, is questionable, particularly for non-native English speakers. The potential inaccuracies in these tools can unfairly disadvantage students, particularly those that are already marginalized, thereby exacerbating the challenges in maintaining academic integrity.

Another profound concern that was raised is the diminished sense of agency and accountability among students when AI tools make decisions on their behalf. This raised worries that this could lead to a reduced capacity for independent decision-making and critical evaluation, qualities that are vital for navigating complex, real-world problems. As educational institutions worldwide grapple with these challenges, the balance between leveraging AI for educational advancement and preserving essential human skills and ethical standards remains a critical consideration.

However, the importance of learning about AI - what it is, how it works, and how to develop and use it responsibility - was discussed as important knowledge and skill for students and teachers to navigate these potential challenges.

2.4. Implementing AI in Education

The operational and administrative domains within educational institutions were highlighted as an approachable area for education leaders wanting to initially explore increased use of generative AI in education. By integrating generative AI tools for tasks such as scheduling, email composition, and report editing, schools might significantly enhance their administrative efficiency. Such automation not only streamlines processes but also reduces the manual workload on staff, allowing for a more effective allocation of resources.

The implications of this technological advancement extend beyond mere operational benefits. By releasing educators from time-consuming administrative duties, AI tools might effectively free up valuable time that can be redirected toward teaching and directly supporting students. This shift can potentially enhance the quality of education, as teachers can invest more energy into planning, delivering personalized instruction, and engaging with students on a deeper level.

2.5. Guidance for Schools on Using AI in Education

The integration of Artificial Intelligence (AI) within educational frameworks necessitates a strategic and thoughtful approach, anchored in the educational objectives of the institution. Prioritising educational goals ensures that AI serves as a tool to support and enhance learning outcomes, rather than driving the educational agenda independently. This approach requires a careful assessment of how AI technologies can complement and augment the educational process to meet predefined objectives.

When implementing AI in education, it's crucial to navigate existing policies, if any, related to data privacy and accessibility. These considerations are paramount to maintaining the trust and safety of all stakeholders, ensuring that AI tools are used responsibly and ethically. Moreover, promoting AI literacy among students, educators, and the wider community is essential. This includes understanding not only how to use AI but also grasping the underlying mechanisms that drive AI technologies. Such knowledge empowers users to engage with AI tools more effectively and critically, and to mitigate known and potential risks.

Equally important is the balanced communication of both the benefits and potential risks associated with AI. Stakeholders should be informed about the advantages AI brings to the educational landscape, as well as the challenges it poses, particularly in terms of academic integrity and the ethical use of AI tools. Educators should be guided on how to restructure assignments and assessments to uphold academic standards while leveraging AI's capabilities.

Clarifying the role of humans in the development and application of AI tools underscores the collaborative relationship between technology and human judgment. It's essential that the use of AI in education does not diminish human oversight but rather, complements human expertise and decision-making.

In addition, the impact of AI on the educational process should be continually assessed and evaluated, incorporating feedback from a broad spectrum of stakeholders, including students, teachers, and parents. This feedback loop is critical for identifying areas of improvement, ensuring that AI integration remains aligned with educational goals, and adapting to the evolving needs of the educational community. This comprehensive approach guarantees that the deployment of AI in education is both effective and responsible, enhancing learning experiences while safeguarding ethical standards and academic integrity.

2.6. Desired Resources and Assistance from TeachAI

To navigate the rapidly evolving landscape of Artificial Intelligence (AI) in education, it is essential to have access to resources that offer insights, reviews, and updates on AI tools and platforms. For parents and students seeking safe and useful AI platforms, the expert group noted that a curated list that evaluates these tools based on their educational value, ease of use, and privacy standards would be invaluable. This list could be part of a larger resource that offers comprehensive reviews of different AI tools for education, highlighting their features, potential applications in learning, and any limitations or considerations to bear in mind.

For educators, staying abreast of the latest developments in AI and education is crucial. The expert group also suggested the creation of a dedicated platform, such as a newsletter, website, or podcast, which could serve as a central hub for information, offering insights into emerging technologies, pedagogical strategies, and practical applications of AI in the classroom. This resource could feature expert interviews, case studies, and tutorials to enrich educators' understanding and implementation of AI tools.

Moreover, there is a need for guidance in navigating the vast array of learning resources available online, to help educators, parents, and students distinguish between high-quality content and misinformation. Assistance in finding relevant and accurate learning materials, alongside strategies for effectively integrating AI into educational practices, would address this need.

The expert group agreed that SEAMEO is well-positioned to play a pivotal role in this context. By engaging local educators and leveraging its network - including its participation in TeachAI, SEAMEO could facilitate the dissemination of AI knowledge and best practices across the region. This could include organising workshops, webinars, and conferences focused on AI in education, as well as fostering collaborations between educational institutions, tech companies, and policymakers to promote AI literacy and ethical AI use.Through such initiatives, the educational community can be better equipped to harness the potential of AI, ensuring that educators are informed, resources are accessible, and students are prepared to thrive in a technologically advanced learning environment.

3. Reflection on the AI Guidance for Schools Toolkits

The expert group also reviewed the TeachAI initiative's draft AI Guidance for Schools Toolkits and provided their opinions which can be summarised as follows.

3.1. Usefulness

The most helpful aspect of the Toolkit is the framework for incorporating AI in education, which provides a clear and comprehensive guide for schools on how to implement AI in a responsible and ethical way. This framework is complemented by a number of other resources, such as the seven principles for AI use, sample school guidance, letters to staff and parents/guardians, and class and student policies.

3.2. Possible Improvements

The expert group would like to see the Toolkit improved by making it more accessible to different audiences, providing more specific examples and guidance, and including more case studies and resources on localising AI use in education. They also suggested additional resources, such as infographics, sample implementation processes, and guidance on how to assess creativity in the use of AI.

3.3. Challenges to implementing the toolkit or AI in education.

The expert group identified a number of challenges to using AI in education, including lack of necessary technology, teachers not understanding AI, concerns over data privacy, resistance to change in traditional education systems, and teachers' ability in being creative during teaching and also teachers' perception. Additionally, some specific challenges were mentioned, such as local languages support, difficulty of access to the internet or even electricity. To address these challenges, it is important to provide teachers with the necessary training and support, to invest in the necessary infrastructure, and to develop policies and procedures that protect student data privacy. In short, the main challenges to using AI in education are technological, pedagogical, and cultural. To overcome these challenges, Southeast Asian countries need to invest in teacher training and support, technology infrastructure, and data privacy protections.

4. Summary

The field of Generative AI is emerging as an important area of interest for the education sector in Southeast Asia, prompting educators to explore its benefits and challenges. Expert discussions have pointed out the need for providing educators with the right resources, guidance, and training to use AI technologies effectively and ethically. These conversations have highlighted AI's potential to improve academic achievements and administrative efficiency, while also drawing attention to important concerns such as data privacy, the importance of teacher training, and ensuring access to technology for all. Looking ahead, it is imperative for educational entities across Southeast Asia to commit to enhancing teacher support, developing robust infrastructure, and enacting policies that facilitate the ethical adoption of AI. This strategic focus aims to prepare students for success in an increasingly digital and AI-integrated learning landscape.

TEACHER

SECTION

USING DYNAMIC SOFTWARE FOR DEVELOPING THAI STUDENTS' ANALYTICAL THINKING SKILLS IN MATHEMATICS

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ABSTRACT

The purposes of this study were (1) to develop student mathematics analytical thinking skills, targeting a benchmark of 70 percent in scores, and (2) to enhance students' mathematics achievement through the 5 E's instructional model and dynamic mathematics software, with the goal of surpassing 70 percent in both scores and classroom performance. A total of 29 students who participated in this study were from a school in Nakhonphanom Province, Thailand during the 2021-2022 academic year. The data collection included the collection of lesson plans, mathematics assessment, and behavioural assessment of analytical thinking skills. The statistics used in the data analysis are mean, standard deviation, percentage, and comparison with quality criteria. The results indicated that the proposed model could improve students' analytical thinking skills across three components: component analysis, relational analysis, and principle analysis, with average scores of 80.25%, 75.75%, and 54.25% respectively. The total mean score for analytical thinking was 70.25%. Additionally, students' mathematics achievement was 75.86%, meeting the established criteria.

Keywords: DMS, 5 E's instructional model, Analytical thinking skills, Mathematics achievement

1. Introduction

Analytical thinking is one of the important skills of the 21st century (Ichsan et al., 2021) it is necessary to develop the analytical thinking skills of a person who will just start their profession (Ratnaningsih, 2013). It is a set of soft skills that help students recognise, collect, and process data related to a problem that needs to be solved efficiently. Analytical thinking affects students' success in many areas (Sebetci & Aksu, 2014) for example, facilitating problem-solving processes in school and daily life (Mayarni & Nopiyanti, 2021) and creative thinking skills (Lestari et al.,2018). Therefore, analytical thinking skills are one of the skills that secondary school students should acquire in the Thai basic education curriculum in 2008, revised in 2017 (Ministry of Education, 2017).

A number of researchers in mathematics education claim that the 5 E's instructional model enhances students' analytical thinking skills (Uttaman & Art, 2012; Ainthason & Chaipichit, 2021). The learning cycle of 5 E's instructional model comprises five phases: engagement, exploration, explanation, elaboration, and evaluation (Bybee, et al., 2006). It begins with engagement during which teachers could show a problematic situation, define a problem, or develop questions under investigation together with the students and students' learning by doing and analysing information for answers (Schallert et al., 2020). Using the 5 E's instructional model, key characteristics in the classroom are (i) the participation of the learner in the science-focused question, (ii) the precedence of evidence in response to the question, and (iii) formulation of explanation from the evidence; (iv) explanations related to scientific knowledge; and (v) communication and justification of explanations (National Research Council, 2000).

Nowadays, digital tools are also used for developing students' analytical thinking and understanding of mathematics which has greatly influenced the education system. They can help teachers and students in teaching and learning mathematics. One of the digital tools for mathematics instruction is Dynamic Mathematical Software (DMS) (Zengin & Tatar, 2017). DMS is a tool that can be used for problem-solving and conceptual understanding. The DMS can be used to construct mathematical objects such as geometric figures, algebraic expressions, and graphs (Sedig & Sumner, 2006). DMS can be used for classroom management and interaction both online and on-site teaching and learning in order to develop students' mathematics concepts and analytical thinking skills (Mukhtar et al., 2021). However, the Program for International Student Assessment 2018 (PISA) suggests that Thai students possess low analytical thinking skills in mathematics as they score below the average score of the OECD countries. Results showed that Thai students can interpret, and perceive without simple commands, but are unable to find a suitable way to solve complex problems associated with the model (The Institute for the Promotion of Teaching Science and Technology, 2021). The Ministry of Education (MOE) reported that the students' average scores on the National Education Test (O-NET) of students at a lower secondary level at a school the year 2017-2020 of Chumchon Bankampok Thadokkeaw school are below the average national score of Thailand. From analysing the test items of O-NET, students should be able to apply their analytical thinking skills to solve real-world problems. From observing student behaviour in the mathematics classroom at Chumchon Bankampok Thadokkeaw school, it was found that students lacked analytical thinking skills. Therefore, teachers should design activities and teaching strategies to develop students' analytical thinking skills according to Table 1.

This research addresses the development of students' analytical thinking skills, which can be categorised into three components as follows: 1) component analysis, 2) relational analysis, and 3) principle analysis (Munkham, 2005). Students can apply their knowledge in daily life. The tools were tried out with students, and data were collected and analysed for development and feedback. This research provides a guideline for developing students' analytical thinking skills and mathematics achievement in mathematics instruction by using DMS and 5 E's instructional model. Implementing DMS in the classroom to foster mathematics learning students can be done via smartphone which facilitates learning for students. It also develops students' thinking skills through real practice in simulated situations.

2. Literature review

2.1 Conceptualising: Student analytical thinking skills in mathematics

Analytical thinking skills are one of those skills within the cognitive abilities of 21st Century skills (Mayarn & Nopiyanti, 2021). Analytical thinking is an important foundation for learning and living, as it consists of important skills: classification, grouping, error analysis, application, and prediction (Marzano, 2001). These analytical skills are essential for the development of the mathematics learning process enabling students to effectively solve mathematical problems (Belecina & Ocampo, 2018). This involves considering various factors with logical reasoning and offering innovations. It is important to understand the components of the situation, and be able to scrutinise and break down facts (Qolfathiriyus et al., 2019). Therefore, three types of analytical thinking abilities must be operationally defined: analysis of elements, analysis of relationships, and analysis of organisational principles (Art-In & Tang, 2017).

2.2 Dynamic software for promoting analytical thinking skills

Mathematical software is Computer technology in mathematics education is classified as Computer Algebra Systems (CAS) and Dynamic Geometry Software (DGS) (Hohenwarter & Fuchs, 2004) for mathematics teaching and learning (Kilicman et al., 2010). Dynamic Mathematics Software (DMS) has received a lot of attention because of its robust structure that combines DGS and CAS functions (Hohenwarter et al., 2009) such as GeoGebra, Geometer's Sketchpad, Desmos, Mathegon, etc. DMS can connect graphics, algebra, and table representations, as well as provide a dynamic learning environment and ease of use (Birgin et al., 2021). DMS is important for conceptualising and utilising dynamic mathematics and is frequently used as a learning and teaching tool at all levels of education. Learning strategies indicate the strategies adopted by the teacher when using DMS in mathematics education. Different learning strategies could be employed, for example, 5E inquiry Model learning is a student-centred approach in which students are guided to explore issues, find solutions, and organise their knowledge (Maaß & Artigue, 2013). Teachers can build activity/task-based learning to implement students' learning (Yohannes & Chen, 2021). DMS is an auxiliary tool to help students understand the mathematical operation process (Lin et al., 2020). DMS allows students to develop critical thinking skills, creative thinking skills, analytical thinking skills, communication skills, self-confidence, and innovative solutions to mathematical problems, enhancing problem-solving skills such as inquiry, exploration, creation, simulations, and reflection and positively influencing the development of students' STEM competencies (Ruzlan & Kim, 2018; Kramarenko et al., 2020; Wijaya et al., 2021; Yohannes & Chen, 2021). In addition, it allows students to develop decision-making, mathematics achievement, mathematics conceptual, motivation to learn, organise information, and support the investigations, exploration, reflection to understanding and reasoning in mathematics. Studies of different phenomena and help in different topics are discussed (Ziatdinov & Valles, 2022; Guerrero-Ortiz & Camacho-Machín, 2022). Here are some advantages of the 5 E's instructional model, namely: 1) encourages students to recall their previous knowledge, 2) helps develop students' scientific attitudes and their thinking abilities, 3) directs the students' focus on one problem to support conceptual understanding, 4) develops the students' potentials, 5) trains students to express a concept verbally, and 6) engages students in exploring, expanding and evaluating the concepts.

2.3 Earlier results in studying the enhancement of mathematical skills through mathematics software

Mathematical skills are conceptualised as a separate area that includes verbal components (number knowledge, counting, computation, and reasoning) and nonverbal components (mathematics notation, reasoning in time and space, and computation) (Daniel,2004). Analytical thinking involves using mathematics skills to understand ideas, discover relationships among the ideas, draw or support conditions about the ideas and their relationships and solve problems involving the ideas (Sam & Yong, 2006; Khusna, 2020; Huincahue et al., 2021). However, developing mathematical skills requires appropriate teaching tools and methods. Mathematical software is a software program designed for both teaching and learning, whose first and foremost goal is to make mathematical concepts clearer and easier for students to grasp. It is designed to enable proactive teaching and can, thus, be used to focus on problem-solving and assist with the development of mathematical experiments and concept introduction both face-to-face and in remote class settings (Ziatdinov & Valles, 2022). Students can practise problem-solving on their own through surveys, examinations, and problem simulations. Mathematical software can be used to visualise mathematical concepts as well as to create instructional materials for students. Mathematical software is important to understanding conceptualises and utilising dynamic mathematics and is frequently used as a learning and teaching tool. It supports the investigations, exploration, simulations, reflection to understanding, and reasoning in mathematics and develops mathematical thinking for students, and helps increase motivation and improve mathematical skills, self-awareness, and student learning involvement. However, the learning method is an integral part of being used in conjunction with Mathematical software to enable students to achieve the teacher's goals. 5 E's instructional model learning is an instructional model, where learning through inquiry follows five phases. The five phases are called (i) engagement, (ii) exploration, (iii) explanation, (iv) elaboration, and (v) evaluation (Bybee et al., 2006). Students are guided to explore issues, find solutions, and organise their knowledge through inquiry (Maaß & Artigue, 2013). Teachers can use 5 E's instructional model through Mathematical software that has the potential to foster active and student - centered learning by allowing for mathematical experiments, interactive explorations, as well as discovery learning. to enable students to learn and develop mathematical skills and processes and students develop their self-study and self-discovery abilities (Nguyen & Bui,2021). It also provides a dynamic learning environment for the exploration of the relationship between the concepts (Zengin Y., 2019). In addition to this, it is found that DMS helps students to develop their skills such as reasoning, analytical thinking, argumentation, and communication (Albaladejo et al., 2015). Exposing that using the DMS tongue 5 E's instructional model is able to enhance the learning environment and analytical thinking skills and learning achievement (Ramlee et al., 2019; Ranjan & Padmanabhan, 2019).

3. Research objectives and methods

3.1 The objectives of this research are:

1. To develop analytical thinking skills of students in grade 7 through the 5E inquiry model and DMS, aiming to meet the criteria of 70 percent of the score.

2. To develop mathematics achievement of students in grade 7 through the 5E inquiry model and DMS, with the goal of surpassing 70 percent in both scores and classroom performance.

The sample of this study were 29 students aged 13-14 years old who were first-year students at a lower secondary level at Chumchon Bankampok Thadokkeaw School in the Province of Nakhonphanom (Thailand) of the 2021-2022 academic year, which all students can learn by smartphone.

3.2 Implementation and Process

This research employed classroom action research by Kemmis, McTaggart & Nixon, (2014) together with a qualitative approach; this paper used a teacher-as-researcher methodology. The concept of teacher-as-researcher encourages teachers to be collaborators in revising their teaching and has its roots in action research. Action research is a deliberate, solution-oriented investigation that is owned and conducted by teachers. It is characterised by cycles of problem identification, systematic data collection, reflection, analysis, evidence-based action taken, and problem redefinition. The terms "action" and "research" highlight the essential features of this method: trying out ideas in practice as a means of increasing knowledge about and for teaching, and learning.

This classroom action research encompasses two cycles. In the first cycle, the researcher established the Professional Learning Community (PLC), which is a collaboration of teachers with a common goal of improving student learning (Panich, 2012, Vehachart, 2018). PLC is important in mathematics education as a key goal of teacher development and support students' understanding, analytical thinking skills, and processes (Brodie, 2020). Additionally, PLCs contribute to the improvement and development of lesson plans, mathematics assessments, and behavioural assessment of analytical thinking skills. In the second cycle, the researcher applied the designed activities to the students for 12 hours, in which every hour the teacher observed the behaviour and graded the students' analytical thinking skills through the assigned tasks. When the students have finished studying, they will take a test to measure their achievement. It is characterised by cycles of plan, action, observation, and reflection.

In this study, the researcher studied DMS as tools to help develop students' mathematics skills. GeoGebra, the researchers designed an activity for students to explore problems and simulations for solving them so that they could identify sub-elements of problems in solving problems. Desmos Activity, the researchers selected situational activities to enable students to make connections between simulations by graphing the situation and describing the resulting graph. Students then described the relationship of the elements of a problem and identified the principles that were relevant to the situation to solve the problem. With GeoGebra Classroom and Desmos Activity, teachers can observe students perform real-time activities, enabling teachers to assist students in groups or individually, as shown in Table 1.

Table 1: Lesson plan

Lesson plan	Topic	Analytical thinking skills	Period
1	Meaning of rank pairs	Component analysis Relational analysis	1
2	Graph of ordered pairs on the orthogonal coordinate system	Component analysis Relational analysis	2
3	Using pairs to show a correlation	Relational analysis	1
4	Graph of a linear equation in two variables	Relational analysis Principle analysis	3
5	Solving equations by graphing	Relational analysis Principle analysis	2
6	Reading and interpreting graphs	Relational analysis Principle anal	3
Total			12

The researcher designed a GeoGebra activity for students to create an ordered pair of relationships, then plot and graph them accordingly. Then students were asked to answer the questions, explain the relationship of the elements and solve the problem, as illustrated.

As an example of Desmos Activity, the researcher selected an activity for students to graph in order to solve real-life problems in which students can visualise the relationship graph describe the correlation among the elements of the problem and identify the principles corresponding to the situation.

3.3 Data analysis

In this study, the class analysis revealed that students had analytical thinking challenges, evident in their response behaviours. The 29 students in grade 7 at Chumchon Bankampok Thadokkeaw School were unable to distinguish the problem sub-elements and were unable to explain the relationship of the problem components, and unable to identify principles, rules, or theories that correspond to simulations to solve problems. After that, the researcher designed and selected the activities with DMS through the PLCs process and tried them out with students and debugged them, and then applied to the sample group. In the learning activities, students were divided into groups of 4-5 students, and then the 5 E's instructional model exam process was implemented as follows: At the beginning of the 5 E's instructional model, the teacher started with an interesting warm-up activity. In the second step, this is a survey or answer-finding process. At this stage, students explored activities designed by teachers using DMS with smartphones. The next stage involved explanations provided by the teacher and served as a guide to the fourth stage, which involved an in-depth explanation. The final stage was the evaluation phase in which both teachers and students evaluated the student's assessment. After that, the learning management results were mirrored with a group of PLCs, and any necessary error corrections were implemented.

Research instruments used in this study include 1) The lesson plans for teaching in topic two-variable linear equation for students grade 7 through DMS and 5 E's Instructional Model 6 lesson plans, 12 hours. 2) Mathematics assessments are used to measure the learning abilities of students. This is due to the process of learning and teaching that is a cognitive behaviour, such as remembering, understanding, applying, and analysing (Pradubwate, 2017). It is a four-choice multiple-choice test with 20 items. 3) Behavioural assessment of analytical thinking skills. It is divided into 3 components: component analysis, relational analysis, and principle analysis (Munkham, 2005). It is a three-question subjective exam, scored according to analytic rubrics as shown in Table 2 and the total outcomes of analytical thinking skills in Table 3.

Table 2: The rubrics behavioural assessment of analytical thinking skills: Improved from Munkham (2005)

Analytical thinking skills	Scoring /quality level	Consideration criteria
Component analysis	4 (very good)	Students can completely identify sub-components of situations or mathematics problems.
	3 (good)	Students can identify sub-elements of situations or mathematics problems correctly, but not completely.
	2 (fair)	Students can identify sub-elements of situations or mathematics problems that are mostly inaccurate and incomplete.
	1 (improve)	Students identify sub-elements of situations or mathematics problems incorrectly or indiscriminately.
Relational analysis	4 (very good)	Students can describe the relationships, relevance, connections, or conflicts of sub-elements of situations or mathematics problems accurately, completely, and to the point.
	3 (good)	Students can accurately, completely, and to the point describe the relationships, relevance, connections, or contradictions of the sub-elements of most situations or mathematics problems.
	2 (fair)	Students can accurately and completely describe the relationships, relevance, connections, or conflicts of sub-elements of situations or mathematics problems but may not be relevant.
	1 (improve)	Students incorrectly describe the relationships, relevance, connections, or contradictions of sub-elements of situations or mathematics problems.
Principle analysis	4 (very good)	Students correctly identify principles, rules, and theories that correspond to situations or mathematics problems.

Analytical thinking skills	Scoring /quality level	Consideration criteria
	3 (good)	Students correctly identify principles, rules, and theories that correspond to situations or mathematics problems, but may not be complete.
	2 (fair)	Students identify principles, rules, and theories that correspond to situations or mathematics problems correctly but not completely.
	1 (improve)	Students incorrectly identify principles, rules, and theories that correspond to situations or mathematics problems.

Table 3: The criteria outcomes of analytical thinking skills: Improved from Munkham (2005)

	Scoring /Quality level	Description
Analytical thinking skills	3.51 – 4.00 (very good)	Students possess the ability to thoroughly discern the constituent elements within situations or mathematical problems. They can articulate the associations, significance, interconnections, or discrepancies among these individual elements with precision and completeness. Moreover, students accurately recognise the principles, regulations, and theories that correspond to the given situations or mathematical problems.
	2.51 – 3.00 (good)	Students are capable of correctly identifying sub-elements within situations or mathematical problems, although their identification may not be entirely comprehensive. They can articulate the associations, complete, and succinct descriptions of the relationships, significance, connections, or discrepancies among these sub-elements in most situations or mathematical problems. Additionally, students demonstrate proficiency in recognising the principles, rules, and theories pertinent to situations or math problems, although their recognition may not encompass the entirety of such principles, rules, and theories.
	1.51 – 2.50 (fair)	Students often struggle to identify sub-elements accurately and comprehensively within situations or mathematical problems, resulting in inaccuracies and incompleteness. However, when it comes to describing the relationships, relevance, connections, or conflicts among these sub-elements, they tend to do so with accuracy and completeness, albeit sometimes in a manner that may not be directly relevant. Similarly, students correctly identify principles, rules, and theories that pertain to situations or mathematical problems, but this recognition may not encompass the entirety of these principles, rules, and theories.
	1.00 – 1.50 (improve)	Students often exhibit inaccurate or indiscriminate identification of sub-elements within situations or mathematical problems. Their descriptions of the relationships, relevance, connections, or contradictions among these sub-elements are likewise marked by inaccuracies. Furthermore, when it comes to identifying principles, rules, and theories relevant to the given situations or mathematical problems, students tend to do so incorrectly.

4. Results and Discussion

4.1 Result

The results of this study were as follows:
The results of the analytical thinking skills assessment results of students in grade 7 through DMS and 5 E's instructional model are shown in Table 4.

Table 4: Results of the students' analytical thinking skills (n=29)

Analytical thinking skills	Score		Percentage
	Mean	S.D.	
Component analysis	3.21	0.77	80.25
Relational analysis	3.03	0.98	75.75
Principle analysis	2.17	0.84	54.25
Total	**2.81**	**0.76**	**70.25**

From Table 2 The rubrics behavioural assessment of analytical thinking skills

Table 4 shows the mean score of the students' analytical thinking on learning through DMS and 5 E's instructional model. It was divided into 3 components: component analysis, relational analysis, and principle analysis, with average scores as follows: 80.25 %, 75.75%, and 54.25 % respectively. A total mean score is 70.25 % which is at a good quality level.

Results of the mathematics achievement of students in grade 7 through DMS and 5 E's instructional model are shown in Table 5.

Table 5: Results of the students' mathematics achievement (n=29)

	Students	Accumulated score	Mean	S.D.	Percentage
Score less than 70%	7 (24.14%)	79	11.29	1.25	56.45
Score more than 70%	22 (75.86%)	356	16.18	1.22	80.90
Total	**29 (100%)**	**435**	**15.07**	**2.45**	**75.35**

Table 5 shows the mean score of the students' Mathematics achievements. There were 29 students in this study, 22 of whom accounted for 75.86 percent of the students, and 7 of those who failed to pass the criteria, representing 24.14 percent of the total students. The mean score of the students' scores is 15.07 representing 75.35 percent of the score.

4.2 Discussion

Results of analytical thinking skills and mathematics achievement of students learning activities by using DMS and the 5 E's instructional model were scores of analytical thinking skills and mathematics achievement of 2.81 points (70.25 %). It's at a good quality level, and 15.07 points (75.35%) respectively, which are more than the specified criteria. Since the 5 E's instructional model is an approach to systematic learning management, the students can have self-directed learning through active involvement, discussion, and reflection. In addition, DMS is an auxiliary tool to help students understand and have mathematical thinking process skills. Sometimes traditional learning is boring, so an innovative teaching medium is needed to assist in teaching. Integration of technology into the learning environment in the classroom promotes student learning and enhances mathematical knowledge and skills and the students can learn by doing through technology, and have enjoyable learning experiences in the classroom. In addition, students can share knowledge and interact with classmates as shown in Figure 1.

Figure 1: Students can learn by doing through technology and share knowledge and interact in the classroom

The results also suggest that DMS and 5 E's instructional model may serve as a terrific source to stimulate students' interest, leading to increased self-confidence. Since there was a clear improvement, the DMS and 5 E's Instructional model could be used as a tool to help teach and learn for students. When students pass learning activities, their mathematics achievement have increased, and it has transformed the classroom into a more interactive environment, promoting cooperative and collaborative learning. As a result, teachers need to shift their roles to be facilitators, with the duties of designing, guiding, helping, providing feedback, evaluating, and encouraging students to learn both inside and outside the classroom.

4. Conclusion

The incorporation of the Dynamic Mathematics Software (DMS) and the 5 E's instructional model results in the following: 1) the development of analytical thinking skills of students mean score is 70.25 % indicating at a good quality level. Prior to learning, the researcher had surveyed the students' knowledge through interviews. It was found that students lacked experience with the content, leading to challenges in identification, explanation of relationships, and application of mathematical theories. However, post-learning, students demonstrated enhanced abilities in identifying elements, accurately explaining relationships, and partially relating mathematical theories to situations. 2) the development of the mathematics achievement of students' mean score is 15.07 representing 75.35 percent of the score, aligned with the established criteria. The implemented approach has empowered students with self-directed learning through active involvement, discussion, and reflection which support students in exploring, expanding, and evaluating the concepts related to understanding and reasoning in mathematics. Moreover, students have displayed a positive attitude towards mathematics and demonstrated the ability to systematically apply technology to solve problems.

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ELEMENTARY SCHOOL TEACHERS' INNOVATIVE USE OF ICTS IN SCIENCE AND MATHEMATICS CLASSROOMS

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ABSTRACT

The COVID-19 pandemic boosted the use of information and communication technologies (ICTs) in education. In this study, we explored how U.S. teachers used a variety of ICTs in science, technology, engineering, and mathematics (STEM) classrooms. This paper focuses on the features of the adopted ICTs and the ICT-related challenges STEM teachers encountered at the elementary school level. Particularly, we presented the innovative use of ICTs on the aspects of providing multifarious presentations of subject content and differentiating learning environments for students. We also discussed the challenges caused by ICT integration, including the lack of hands-on learning experiences, students' low engagement, and ineffective assessments. Last, we invited the participants to share their solutions to the ICT integration problems on (a) content presentation and exploration, (b) learning engagement and assessment, and (c) family communication. This study revealed the potential benefits and challenges of incorporating ICTs into elementary-level STEM instruction in both in-person and virtual environments. These findings provide valuable insights and implications for educational policies and practices to support future innovative ICT integration in STEM education.

Keywords: ICTs, Elementary STEM education, Presentation, Communication

1. Introduction

Since the late 1990s, computer-based and online learning initiatives have been implemented in classrooms as an enhancement to students' engagement and learning (Brown et. al., 1998; Sahlin, et al., 2017; Weaver & Nilson, 2005). Information and communication technology (ICT) has become an umbrella term referring to the tools, processes, and resources used to access, manage, communicate, and share information. In the elementary classroom, ICTs have been used in a variety of ways to support teaching and learning by providing students with interactive and engaging digital tools that promote active participation and collaboration. Teachers have also used ICTs to personalise learning and provide differentiated instruction to meet their students' diverse needs (DeCoito & Richardson, 2018). Expectations of the convergence of ICTs and the elementary classroom reached a sudden and dramatic evolution with the onset of the COVID-19 pandemic in 2020. The use of ICTs became increasingly important as many schools transitioned to remote or hybrid learning models and teachers had to adapt their teaching practices to ensure that students continued to receive quality education despite the challenges posed by distance and hybrid learning.

ICTs such as video conferencing platforms, learning management systems, and educational software enable teachers to deliver lessons, provide feedback, and assess student progress. With appropriate adoption and arrangement, these ICTs could enable students to collaborate and work as a group despite not being physically present in the same location. To effectively integrate ICTs into teaching practice, teachers need to know the impacts of integrating ICTs into content areas and recognise the associated pedagogical shifts (Lim & Oakley, 2013). Moreover, teachers have been “encouraged to adopt different technological tools and develop their literacy of technology, content, and pedagogy” (Jang & Tsai, 2013, p. 566). DeCoito and Richardson (2018) concluded that teachers “need an ever-evolving understanding of which technologies exist and their functionalities” (p. 364). In particular, teachers who teach subjects like science, technology, engineering, and mathematics (STEM) in elementary schools may need more attention and support because their students are in the concrete operational stage and need hands-on experience to construct STEM knowledge.

2. Conceptual Framework and Methods

In elementary STEM classrooms, ICTs include interactive whiteboards, educational software and apps, online educational resources, virtual manipulatives, and digital learning games (Bingimlas, 2009). For instance, interactive tools have been used to enhance classroom instruction by allowing teachers to present content more interactively (Lim & Oakley, 2013). Educational software and apps can provide students with opportunities to practice and reinforce concepts learned in class, while online educational initiatives can provide additional materials and information for students to explore (Zhang et al., 2015). During the COVID-19 pandemic, ICTs have evolved into an essential part of elementary education and provided teachers with new and innovative ways to engage students and promote the continuity of students’ STEM learning (DeCoito & Estaiteyeh, 2022). In this study, we explored elementary teachers’ experiences with incorporating ICTs into STEM instruction and identified these technologies’ features as well as the challenges teachers encountered.

The indispensability of integrating technology into the curricula and instruction to increase academic achievements led to a push for teachers to become more technologically literate and adopt different technological tools in their teaching practices (USGPO, 2002). For example, Ally’s (2009) classification of teachers’ ICT use included content-oriented tools (e.g., presenting subject content), production-oriented tools (e.g., creating digital content), evaluation-oriented tools (e.g., assessing learning outcomes), and communication-oriented tools (e.g., interacting with learners). Therefore, teachers must develop their pedagogical skills and explore new ways of incorporating ICTs into their lessons, especially in STEM subjects where hands-on learning is crucial. However, the COVID-19 pandemic highlighted the need for additional support for teachers in implementing these changes effectively, particularly at the elementary level, where students may have varying levels of cognitive development and technological literacy. This study aimed to reveal (a) the types and features of the adopted ICTs in elementary STEM classrooms, (b) the challenges elementary teachers encountered in terms of adopting ICTs and maintaining student engagement in STEM learning, and (c) the strategies elementary teachers used to address the difficulties.

In the 2021–2022 school year, the research team conducted one-on-one interviews with 55 K-12 STEM teachers in a southern U.S. state. Among them, 11 teachers expressed their innovative ICT use and relevant concerns at the elementary level. These participants held elementary teaching certifications and their STEM-related subjects teaching experience ranged from 2 to 38 years. Six were teaching in rural areas, with the rest in urban areas. The 11 semi-structured interviews were audio recorded and transcribed verbatim. The transcripts were then analysed through the constant-comparative method (Strauss & Corbin, 1990) to identify and categorise the ICTs mentioned in the interviews under emerging themes. Although there are many different ways to classify ICTs used in education, we initially dichotomised them into content-specific and non-content-specific categories. We then reported the features, challenges, and solutions for integrating the recommended ICTs into elementary-level STEM instruction.

3. Results and Discussion

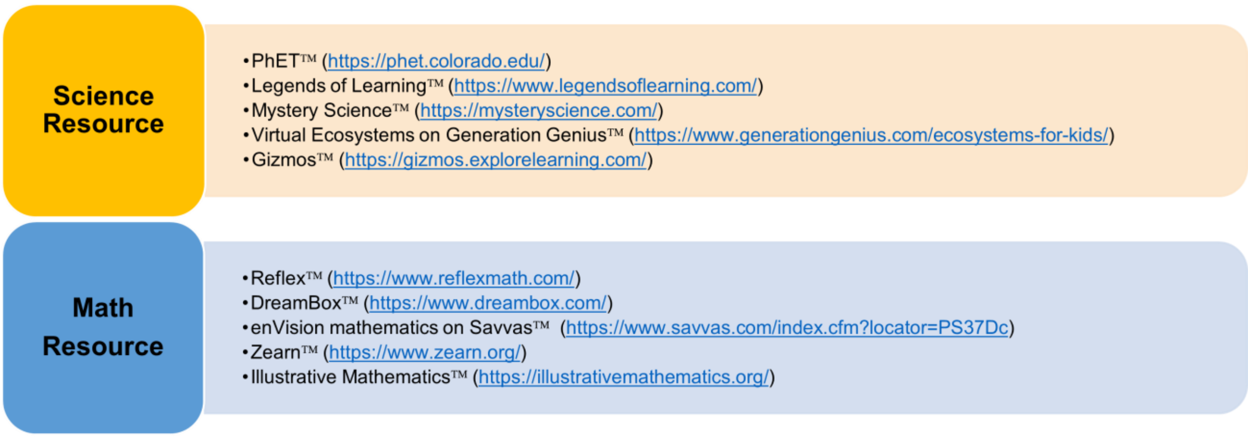
3.1 Incorporation of ICTs into STEM Classrooms

The participants recommended a variety of ICTs for planning lessons, presenting subject content, facilitating students' knowledge construction, assessing learning outcomes, and managing student behaviour in their science and mathematics classrooms. We first shared the ICTs recommended by the elementary STEM teachers.

Although most content-related educational digital resources can be used for a wide range of subjects across different grade levels, the participants particularly enumerated resources helpful for introducing new knowledge, engaging students in constructing and visualising the concepts to be learned, and evaluating and tracking students' understanding and learning. For example, math teachers incorporated video tutorials from the Khan Academy and Math Antics websites to introduce new knowledge because "sometimes kids need a different or extra voice/perspective to understand [mathematics concepts]" (V02EM). They further highlighted that these content-specific video tutorials provide step-by-step explanations of math concepts with rich representations, which supplement mathematics instruction well and can be easily embedded into Google Classroom, the most widely used platform in school districts. In addition, the teachers believed that students take advantage of watching these videos at their own pace or in any sequence that benefits their learning to maintain their learning agency.

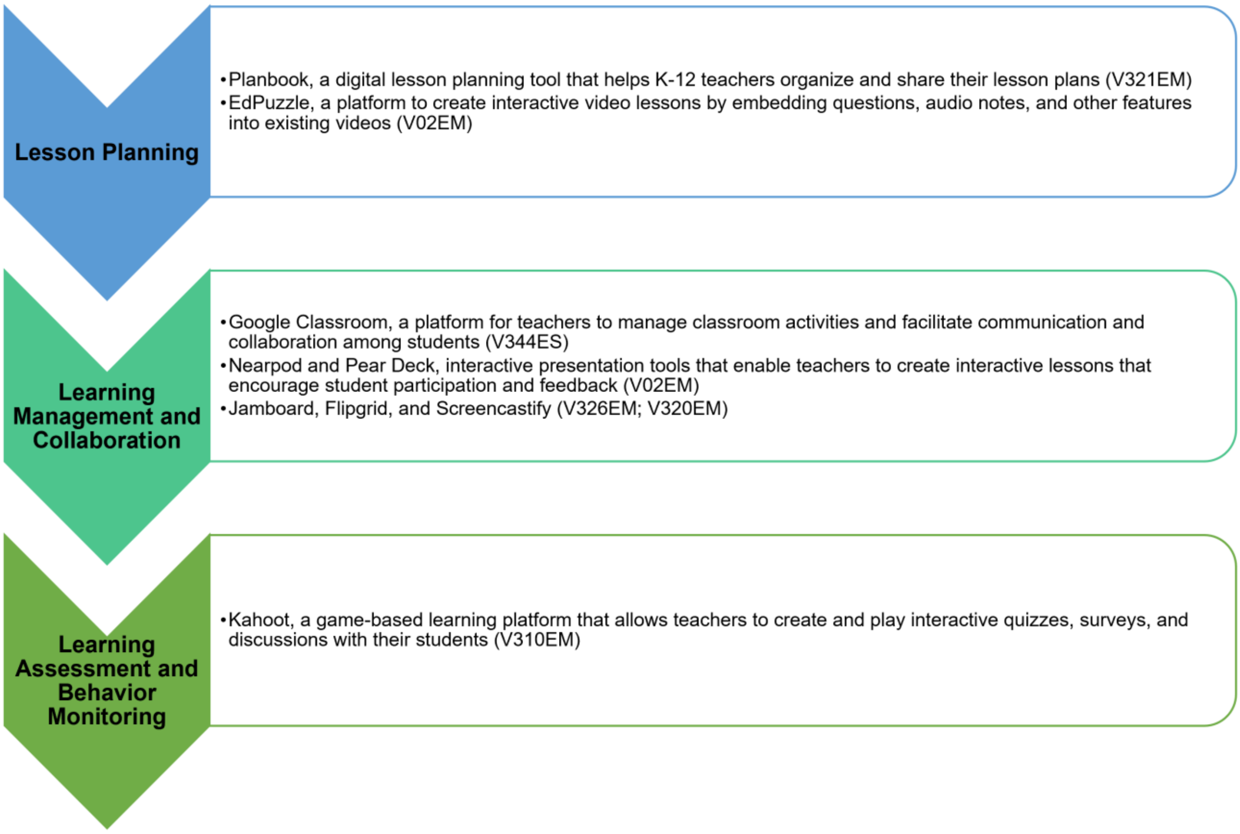
After teachers introduced a new concept, content-specific learning resources were adopted to advance students' subject knowledge construction. Figure 1 presents the science and mathematics resources that elementary teachers incorporated into their STEM instruction.

Figure 1: Content-Specific ICTs for Elementary Science and Mathematics Instruction



Most elementary teachers taught multiple STEM subjects, so they also shared some non-content-specific online resources for them to (a) plan and present lessons, (b) manage student learning and collaboration, and (c) assess student performance and monitor student behavior. Figure 2 shows the suggested resources with short descriptions.

Figure 2: Non-Content-Specific ICTs for Elementary Science and Mathematics Instruction



3.2 ICTs that Innovate STEM Teaching and Learning

In this section, we elaborated on how the aforementioned ICTs were utilised to innovate STEM teaching and promote student learning in both in-person and virtual environments. In addition, the challenges along with solutions regarding integrating ICTs into science and mathematics teaching are presented. The discussion focuses on three themes: (a) content presentation and exploration, (b) learning engagement and assessment, and (c) communication.

3.2.1 Presenting and Exploring the Content

The participants' adoption of ICTs aimed to provide multifarious presentations of the subject content they were delivering and expose students to versatile means of knowledge exploration and construction. To these teachers, it is important for students to actively interact with the learning materials instead of passively receiving information. One participant shared, "I've used a lot of interactive slide decks for teaching, or the kids use it independently" and while teaching science, she recommended PhET, in which "[S]tudents can put this boiling water, take the boiling water off the fire, and watch what happens" (V346EM). In addition, it is also crucial to differentiate learning environments for students. One math teacher shared, "Reflex and Dreambox help because they are differentiated. Text-to-speech functions have been very helpful, as well as Google drawings. Students who struggle with writing and get their thinking across in other ways through tech like those things" (V02EM). Another math teacher echoed the use of Reflex and claimed that it benefits students by "developing fluency in basic math facts with four operations to further achieve mastery in math concepts" (V310EM).

For some participants, incorporating digital resources into teaching not only benefited student learning but also promoted their ICT professional development. For example, one math teacher asserted:

> I'm able to create lessons that have more to them than I used to. It's not just reading a chapter and answering questions, it's reading, video, experiments, revising, and going back to research, and there are so many resources for my own learning. Plus, doing digital lesson plans takes much less time than handwriting everything. (V312EM).

Lastly, mathematics programmes such as "Illustrative Mathematics" were prioritised because they aligned with the curriculum adopted in the participant's school district.

To help students explore science concepts, our participants suggested introducing science lessons within a more interactive environment like video games. One science teacher recommended Legends of Learning by saying "[I]t's not about points or whatever. The kids play video games and things as they go through, but everything that they're doing is teaching them concepts" (V344ES). Other favoured features included (a) being funded by the school district, (b) providing a simulated lab with hands-on elements, and (c) benefiting both in-person and virtual learners. Unfortunately, science teachers faced enormous challenges regarding content delivery since COVID because adopting ICT to guarantee the same hands-on science learning experience has been either costly or difficult to implement. As a result, the participants in this study concluded that they have so far been able to use only a limited number of inexpensive and easily accessible online resources. They reiterated that most online resources that allow students to observe and further manipulate phenomena like animal populations in an ecosystem were only appropriate for upper-grade learners, implying the difficulty of finding suitable online science labs for K–2 students.

3.2.2 Engaging and Evaluating Learning

Our participants engaged elementary students in science learning using interactive simulations like Virtual Ecosystems and Gizmos. However, they admitted that the uncertainties caused by the pandemic made it difficult to effectively engage students. For example, one science teacher emphasised that there were "very few opportunities for online students to do hands-on activities, just because the parents may not have had the materials" (V345EM). Another science teacher recommended "Mystery Science," which offers ready-made science lessons as well as resources and guides the students step-by-step through the lessons. However, she shared her frustration by saying "[W]hen we did virtual labs, my students would just watch the lab on the presentation and not actually partake in doing the lab themselves" (V328ES). One math teacher expressed her concern by saying "[T]he kids who need to use virtual manipulatives often won't seek them out or know which ones to use" (V02EM). Another math teacher admitted, "[I]t's still not the same as letting the kids actually be there to do the hands-on experiment themselves. Not near the same" (V311EM). In summary, the main difficulties that prevented students from engaging in learning were caused by the lack of available resources at home, the loss of learning motivation, and low student accountability.

Fortunately, some solutions were proposed to increase engagement by integrating ICTs into teaching. For example, one math teacher tried to incorporate different non-content-specific apps like Nearpod, Google Classroom, Jamboard, Flipgrid, or Screencastify to increase interactivity, making sure her students "could have a drawing or could move blocks, so it'd be more trying to manipulate forms and problem solve on a virtual level" (V320EM). To assess students' STEM learning, one math teacher said, "The kids love getting to write and draw responses and Pear Deck makes formative assessments a breeze…Mainly it increases student engagement, and it allows me to easily give and record data on formative assessments" (V02EM). Another math teacher praised the gaming feature in some ICTs:

> I can do a review on division by playing that game where the students can interact [on Reflex]. They love it, it does help increase the excitement in the learning atmosphere because it can cause students to be more excited about learning. (V310EM).

3.2.3 Communicating with Students and Parents

Our participants admitted the importance of building efficient communication with students and their parents, especially with the online cohort. One math teacher directly pointed out that "Google Forms helps communication" (V310EM) and another math teacher recommended the "enVision mathematics" developed by Pearson Learning because "[I]t is helpful with virtual learning for teachers to use in class and for parents to use at home" (V321EM). To most participants, the affective aspect is as important as the cognitive aspect in their virtual teaching and classroom management. For example, one teacher shared, "[S]ometimes I record videos for quarantining students so that they can see my face and hear from me. It helps me to keep them connected and know that I care about them" (V310EM). Lastly, a kindergarten teacher emphasised that doing hybrid teaching with younger learners could be extremely challenging for teachers and shared how she handled that:

> It is challenging because I have 20 [young kids who are all] six years old to manage in my classroom, as well as have two or three of them on a Zoom call, but I try to incorporate the work that they are doing at home independently with the help of an adult, something that they are familiar with or something that they've done before. (V321EM).

In these cases, our participants either needed to provide extra accommodations or relied on assistance from the family, which led to compromises in the scope of selecting content knowledge and delivery methods. For instance, one math teacher decided that "[I]f it's going to be brand new information for the students, I choose to do either a pure Zoom meet or just in person completely" (V321EM). One science teacher stressed the difficulty of monitoring students during the virtual experimentation time by saying "[I]t's hard because there's only so much you can do with a kid sitting in front of a screen if they won't participate or if they won't do work" (V344ES). Accordingly, she decided to reduce the complexity of conducting experiments with students studying at home and concluded, "I would send home to parents that we would be doing a hands-on investigation the next week. I always made sure I just used common stuff that most homes would have. A bowl, water, paper towels, really simple things" (V344ES). Lastly, one math teacher shared:

> We have a homework helpline four days a week for two hours an evening where certified teachers can Zoom with students. I spent many hours on the phone and texting parents to help them through their problems last year when COVID-19 first hit. (V312EM).

Although a homework helpline seemed to work then, she suggested that the whole school district or even the education system should strive to help teachers establish a more effective communication mechanism via integrating ICTs efficiently to avoid overloading teachers.

4. Conclusion

The COVID-19 pandemic significantly changed the role of technology playing in education around the world and ICT integration has become a new essential in STEM teaching and learning. In this article, we reported STEM teachers' ICT integration at the elementary level and elaborated on how specific ICTs were adopted to innovate STEM instruction in the aspects of presenting content, managing and assessing learning, and communicating with students. We also discussed the relevant challenges regarding the lack of resources at home as well as students' low engagement and accountability. The potential solutions shared by our participants could be used to initiate a think tank in STEM education to benefit future ICT integration across multiple grade levels. With the knowledge and insights this study provided, the innovative integration of ICTs in STEM teaching and learning can be optimally supported in the post-pandemic era. It is worth noting that ICT-related hardware, software, training, policies, and practices all play a crucial role in the integration process (Bingimlas, 2009). As the participants shared, successful ICT integration in STEM education relies on the teacher's professional skills of identifying legitimate, accessible, useful, and effective ICTs "be innovative and create lessons that bring meaningful learning to students" (V346EM).

Acknowledgment

This study was funded by Team Up for Education and Health Funds Strategy of the WE CARE Initiative at the University of Arkansas, Fayetteville, AR, USA.

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STUDENT

SECTION

USING YOLOV5 MACHINE LEARNING FOR GALLSTONE DETECTION

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ABSTRACT

Gallstones are a major health problem affecting the quality of life in Thailand, but the detection of gallstones can be difficult. By applying machine learning, we can create prediction models to detect gallstones. To train the developed model, 1320 anonymised images were collected from patient Endoscopic Retrograde Cholangiopancreatography (ERCP) videos, with 1200 images used for training and 120 images for testing. The Yolov5s model trained over 50 epochs was chosen as the most effective for identifying gallstones, with a precision of 97% and an F1 score of 98%. An application prototype was also developed to enable physicians to submit ERCP images for gallstone identification.

Keywords: Gallstone, Yolov5, Machine Learning, Detection, Application

1. Introduction

Gallstones are small stones that form in the gallbladder. They can cause sudden, severe abdominal pain, and complications can develop, such as inflammation of the gallbladder which can lead to death. In north-eastern Thailand, gallstones occur in about 10 – 20 % of the population, according to Bangkok Pattaya Hospital. (2024). Thais are very likely to have a recurrence of gallstones, which means a high cost of treatment for both the patient and the government. Gallstones can range from the size of a grain of sand to the size of a golf ball.

A procedure called endoscopic retrograde cholangiopancreatography (ERCP) uses upper gastrointestinal endoscopy and x-rays to diagnose and treat problems with the bile and pancreatic ducts (National Institutes, 2016). An ERCP is performed when gallstones form in the gallbladder and become stuck in the common bile duct, narrowing or blocking the bile or pancreatic ducts. In some cases, gallstones can be difficult for the physician to detect, leading to misdiagnosis of the problem (Mayo, 2021). Thus, we propose to use artificial intelligence (AI) with machine learning techniques to develop a deep learning model to detect gallstones, then develop a mobile application which physicians can use to submit ERCP images for assistance with gallstone detection.

1.1 Deep Learning Models

A subset of machine learning, deep learning simulates human brain behaviour by using neural networks. A neural network with three or more layers can learn from data much more effectively than one with a single layer, allowing it to make accurate predictions (IBM, n.d.). With deep learning, artificial intelligence services and applications can be developed that help automate tasks and improve efficiency. Many everyday products and services, as well as emerging technologies like self-driving cars, use deep learning technology. A computer vision deep learning model called Yolov5 can identify objects in images accurately. There are four main versions of Yolov5: small (s), medium (m), large (l), and extra-large (x). In each version, accuracy rates are increasing progressively, and training time varies. Preliminary results indicate that Yolov5 performs exceptionally well when compared to other state-of-the-art techniques. Yolov5 variants train faster than EfficientDet, and the most accurate Yolov5 model, Yolov5x, can process images up to four times faster and with similar accuracy to the EfficientDet D4 model. (Solawetz, 2023).

When evaluating models, the Precision and the F1 score are essential factors to consider when evaluating the overall results of the trained AI. Precision refers to the ability of the detector to make correct classifications. Equation (1) is used to calculate the percentage of the precision, where True Positives (TP) is the number of samples correctly predicted as “positive” and False Positives (FP) is the number of samples incorrectly predicted as “positive".

$$Precision = \frac{TP}{(TP+FP)} \quad (1)$$

Recall refers to the percentage of data samples that a machine learning model correctly identifies. Equation (2) is used to calculate the F1 score of the model.

$$F1\ Score = 2 \times \frac{Recall \times Precision}{Recall + Precision} \quad (2)$$

If the precision and F1 score of the training result are too low, it is necessary to increase the number of images or epochs and run the process again until a satisfactory result is achieved. (Kundu, 2020).

1.2 Application Development

Developers often use React Native, a JavaScript framework, to create native mobile applications for iOS and Android devices. Rather than targeting the browser, React Native targets mobile platforms. As a result, code can be developed for Android and iOS devices simultaneously as most of the code is shared across platforms.

Here, React Native was used for front-end development to create the homepage. The front-end is everything the user sees and interacts with. JSX and markup similar to XML are used to write React Native applications. A React Native "bridge" then invokes the native rendering APIs in Objective-C (for iOS) or Java (for Android). As a result, the application is rendered using real mobile UI components rather than web views, and it will look like any other mobile application. Furthermore, React Native provides JavaScript interfaces for platform APIs, which allow your apps to access platform features such as the camera or location of the user (O’Reilly, n.d.). For the back-end, Python was used to develop the server-side of the application. The back-end involves the technologies responsible for storing and securely manipulating user data.

2. Methods

2.1 Image Collection and Processing

ERCP gallstone video from Dr Vittaya Jiraanankul, Urinary Tract Specialist, Phramongkutklao Hospital, was obtained then converted into 1,320 raw images (Figure 1), 1,200 of which were used for training and 120 for testing. To create the dataset for training the deep learning models, the gallstones from each image were identified using Image Annotating, as shown in Figure 2, then the images were resized to 640 x 640 pixels, (Figure 3).

Figure 1: Raw image

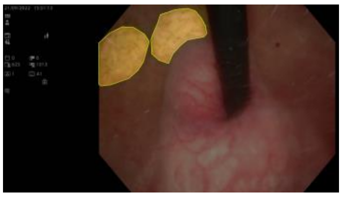

Figure 2: Annotated image

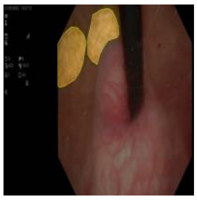

Figure 3: Resized image

2.2 Model Training

To determine the most effective version of Yolov5, three of the versions (small, medium, and large) were trained on the image dataset for 200 epochs and the precision and F1 scores determined. Once the most effective Yolov5 version was determined, that version was trained for 50 and 200 epochs and the most effectively trained model was selected.

3. Results and Discussion

3.1 Model Training

The results of the initial testing of the three versions (Yolov5s, Yolov5m, and Yolov5l), trained over 200 epochs, are shown in Table 1. As can be seen, all three versions have the same F1 Score, however the small version (Yolov5s) returned the lowest percentage. The Yolov5s version was thus selected for further model training to avoid the problem of overfitting. Overfitting occurs when a model cannot generalise and instead fits too well on the training data set.

Table 1: Precision and F1 Score of all three Yolov5 versions used in initial testing

Version	Epoch	Precision	F1 Score
Small	200	99.1%	98.0%
Medium	200	99.9%	98.0%
Large	200	99.5%	98.0%

The results of the training of the Yolov5s model on the dataset for 50 and 200 epochs is shown in Table 2. After 200 training epochs, the precision was 99.1%, which was concerning in terms of overfitting. In order to avoid this, the training was reduced to 50 epochs to reduce the precision. The precision after 50 epochs was 97.5%, which gives a more effective model than the 200-epoch training, while the percentage of the F1 Score remained the same. In order to reduce the problem of overfitting and get a more consistent gallstone detection model, the Yolov5s model trained for 50 epochs was selected for use in the mobile application that was developed.

Table 2: Precision and F1 Score of the Yolov5s model trained for 200 and 50 epochs

Epochs	Precision	F1 Score
200	99.1%	98.0%
50	97.5%	98.0%

3.2 Mobile Application

The gallstone detection application was kept as simple as possible, with only four pages. The first is the language selection page (figure 4A), where the user can choose the language of the application between English and Thai. The second page (figure 4B) is the main page where the user can select an ERCP image to upload to detect gallstones. The third page (figure 4C) is the result page which shows the result of the detection. The last page is the About Us page (figure 4D), which contains personal information about the developers. While the application has been developed and tested internally, further testing is needed before it can be released for general use by physicians to assist with diagnosing patients.

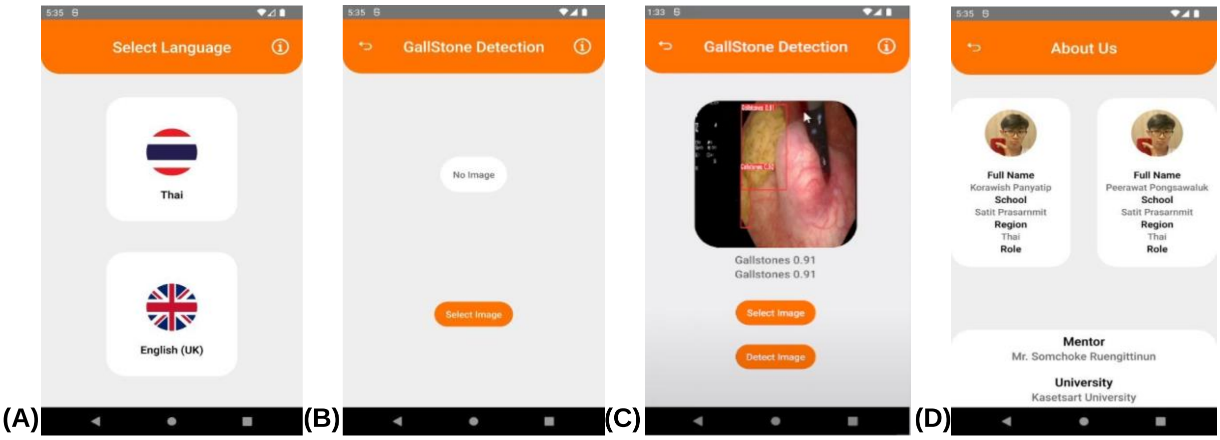

Figure 4: (A) Language selection page (B) Detection page (C) Result page (D) About us page

4. Conclusion

A deep learning model to detect gallstones using Yolov5 machine learning was developed. The model was trained over 50 epochs on a dataset of ERCP images. The model demonstrated high effectiveness in gallstone detection, with an F1 Score of 98.0% and a precision of 97.5%. A mobile application was also developed to enable physicians to upload ERCP images for gallstone detection using the developed model.

The possibility of using a machine learning model to accurately detect gallstones has been demonstrated here. However, the authors must emphasise that this study is a preliminary proof-of-concept. Much further development and verification of the model and testing of the mobile application is needed before this can be used by physicians in medical practice.

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