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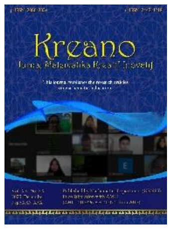

STEM Trails: Enhancing STEM Education through Math Trails with Digital Technology

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Abstract

This study aims to explore the development of STEM Trails to improve STEM Education through the integration of Math Trails activity with Digital Technology. An exploratory study initiative engaged researchers, teachers, students, and programmers. Data was collected through discussions and observations and then evaluated to create STEM Education through Math Trails utilizing Digital Technology. The study demonstrated the successful development of STEM Trails, comprising the STEM Trails platform and the creation of STEM Education activities utilizing Math Trails on the platform. STEM Trailblazers create paths with goals focused on science, technology, engineering, and mathematics using elements found in the surroundings. The trail and tasks are posted on a website for STEM Trail walkers to access and investigate via an application. STEM Trails enable the comprehensive exploration of science, technology, engineering, and mathematics through physical or virtual means. The study suggests that STEM Trails can serve as a mathematics learning approach that mixes outdoor activities with digital technologies and incorporates other subjects. Math Trails is a traditional concept that has been innovatively combined with digital technologies and diverse activities. This method must be broadened and refined by adjusting to the specific circumstances, conditions, and requirements, and then executed in different settings.

Keywords: Digital Technology; Math Trails; STEM Education

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Abstrak

Penelitian ini bertujuan untuk mengeksplorasi pengembangan STEM Trails untuk meningkatkan STEM Education melalui integrasi aktivitas Math Trails dengan Digital Technology. Sebuah inisiatif penelitian eksploratif melibatkan peneliti, guru, siswa, dan programmer. Data dikumpulkan melalui diskusi dan pengamatan dan kemudian dievaluasi untuk menciptakan STEM Education melalui Math Trails menggunakan Teknologi Digital. Studi ini menunjukkan keberhasilan pengembangan STEM Trails, yang terdiri dari platform Stem Trails dan penciptaan kegiatan STEM Education menggunakan Math Trails di platform tersebut. STEM Trailblazers menciptakan jalur dengan tujuan yang berfokus pada ilmu pengetahuan, teknologi, teknik, dan matematika menggunakan elemen yang ditemukan di sekitarnya. Trail dan tugas diposting di situs web untuk STEM Trail walker untuk mengakses dan menyelidiki melalui aplikasi. STEM Trails memungkinkan eksplorasi komprehensif ilmu pengetahuan, teknologi, teknik, dan matematika melalui sarana fisik atau virtual. Studi ini menyarankan bahwa STEM Trails dapat berfungsi sebagai pendekatan pembelajaran matematika yang menggabungkan kegiatan outdoor dengan teknologi digital dan mengintegrasikan mata pelajaran lainnya. Math Trails adalah konsep tradisional yang telah digabungkan secara inovatif dengan teknologi digital dan berbagai kegiatan. Metode ini harus diperluas dan disempurnakan dengan menyesuaikan dengan keadaan, kondisi, dan persyaratan tertentu, dan dijalankan dalam pengaturan yang berbeda.

INTRODUCTION

Integrating STEM (science, technology, engineering, and mathematics) into comprehensive learning activities has been shown to help students develop 21st-century skills, as demonstrated in many research (Bergsten & Frejd, 2019; Kertil & Gurel, 2016). STEM education is an interdisciplinary method of teaching that combines theoretical principles with practical applications (Holmlund et al., 2018). STEM fields offer abundant chances for students to participate in rigorous and stimulating mathematical investigations that extend into several other disciplines (Griffiths, 2011). Lavicza et al. (2018) include design, creativity, and the arts broadly within STEM Education to transition from STEM to STEAM Education.

Various resources in our environment might serve as sources of inspiration for learning through a STEM approach. Various sites and artifacts related to culture offer contextual STEM field experience in numerous locations. These domains can be explored by directly interacting with landmarks and other objects of local significance. A landmark is a stationary and easily identifiable location in the landscape (Zheng et al., 2016). Landmarks can be found in places, neighborhoods, and entire regions. Landmarks capture the interest and recognition of the public. Many sites and settings offer chances to apply STEM ideas. A landmark can refer to a specific spot (e.g., a tourist destination), a line (e.g., a roadway), or an area (e.g., a city) (Zheng et al., 2016).

Some problems in STEM-related to a particular place or object can be designed into a task and then linked to other tasks to form an exploration path. In mathematics, this idea is known as the math trail (Shoaf et al., 2004), which can be traced to explore mathematics in the surrounding environment. Using current technological advancements, math trails can be developed using mobile applications supported with GPS features (Cahyono, 2018; Cahyono et al., 2020; Cahyono & Ludwig, 2019; Zender et al., 2020). Some Project has been done to integrate the uses of mobile technologies and the idea of a math trail (Cahyono et al., 2020; Gurjanow et al., 2019; Jablonski et al., 2021; Ludwig & Jesberg, 2015; Taranto et al., 2021).

Outdoor education in mathematics is a well-established concept. The integration of outdoor math study, STEM Education techniques, and mobile devices seems innovative. Utilizing the STEM Education approach can assist explain mathematical applications effectively when taking mathematics outside. This activity enhances students' understanding of the practical application of mathematics in daily life, especially in STEM subjects, by incorporating mobile technology.

Mobile devices offer a chance to incorporate key aspects of successful learning, like interesting information, group collaboration, and real-life situations (Wijers et al., 2010). Digital tools are frequently utilized for problem-solving, and digital simulations can analyze the impacts of different system or environmental variables (Greefrath & Siller, 2018; Jarvis et al., 2011; Lavicza & Koren, 2015). Advancements in technology related to the Fourth Industrial Revolution, such as Augmented Reality/Virtual Reality, Artificial Intelligence, Autonomous systems, and the Internet of Things, have created opportunities for the creation of STEM Education programs incorporating math trails with digital technology (Christensen & Eyring, 2011). The study aimed to answer how STEM Trails can be designed to enhance STEM Education through Math Trails using Digital Technology by creating an innovative educational program.

METHOD

This study employed an exploratory design research methodology to address the research questions, conducted in laboratories and classrooms with the participation of teachers and students. This method includes researchers and practitioners (stakeholders) engaging in discussions regarding research, development, implementation, and dissemination (Bakker, 2018; Gravemeijer & Terwel, 2000). Exploratory research generates detailed, comprehensive, and reliable data, which is then used to form well-founded hypotheses (Stebbins, 2001). We have carried out a series of pilot studies to create a learning environment based on the concept of Didactical Situations in Mathematics (Brousseau, 1997). We have created a digital interactive instructional platform.

The study involves educators and 25 students. The instructors are trailblazers in STEM, establishing STEM trails, while the students act as trail walkers who navigate the designated routes and tackle the problems they face. The data was gathered through discussion and observation and subsequently evaluated to develop STEM Education utilizing Math Trails with Digital Technology. The study used observation sheets, discussion guides, and task matching standards to analyse student work in the STEM Trails program. Data analysis is qualitatively conducted using triangulation.

RESULTS AND DISCUSSION

STEM Trails Platform

The research has developed a platform that may be reached at https://stemtrails.id. The website is segmented into different sections: a start page, a news area for current information, a Trails section for publicly available STEM Trails, a Trails section for project and team information, and a dashboard section (Figure 1). Users on this platform are categorized into three groups: STEM Trail Administrator, STEM Trailblazer, and STEM Trail Walker. The STEM Trail Administrator supervises the portal's monitoring and manages access for the STEM Trailblazer and STEM Trail walker. STEM Trailblazers create STEM activities and challenges inspired by real-world objects or occurrences, which are subsequently shared on the website. STEM Trail walkers utilize the platform to navigate paths and complete objectives along designated or self-selected routes. Trail walkers can access jobs and paths either directly or by logging onto the platform, depending on the configuration set by trailblazers.

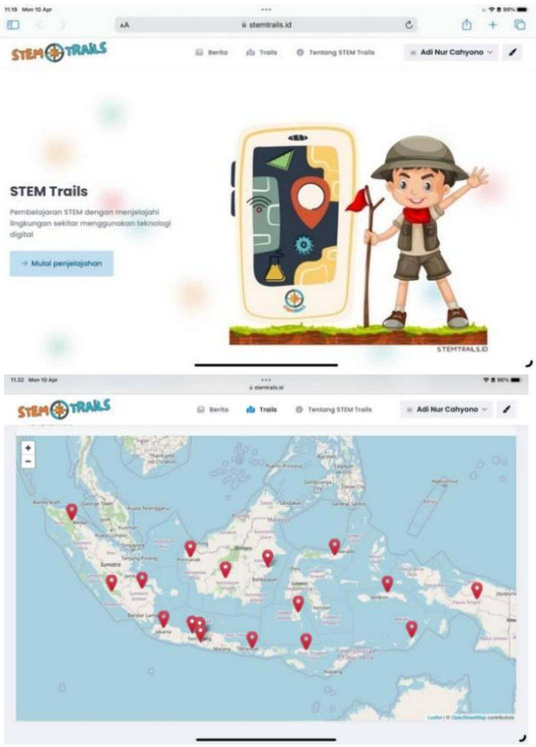


Figure 1. The STEM Trails portal and several trail locations were created by STEM Trailblazers

STEM Tasks include titles, descriptions with explanations of objects and problems, locations shown on a digital map or GPS coordinates, problem solutions, integrated STEM fields, keywords, and a set of instructions or questions presented in various activities for STEM Trail participants to finish. Five STEM tasks can be connected to create a STEM Trail as shown in Figure 2. These tasks may be created by educator or by other educators whose tasks are accessible for usage by other innovators.

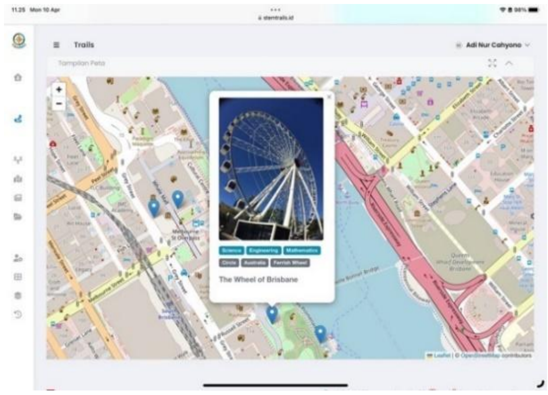
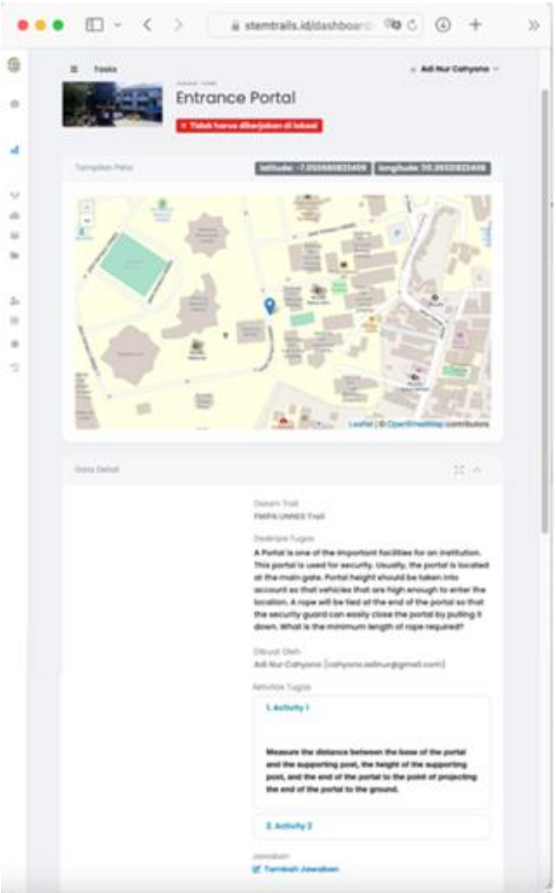


Figure 2. STEM Trail and Tasks

STEM Trails Activities

STEM Trails activities start with trailblazers investigating the physical environment for items or occurrences related to science, technology, engineering, or mathematics and incorporating them. Trailblazers define the item or event and address design-related issues. STEM Trailblazers provide tasks on the website that are connected to other activities to create a STEM Trail consisting of approximately four tasks. Two categories of jobs and trails are created: ones that require completion on-site and ones that can be done remotely. Tasks and paths can be limited to STEM Trail walkers with an account or made publicly available for access without checking in.

Figure 3 illustrates how walkers follow the trail and address any tasks that may emerge. Encountering the task of considering a Portal as a vital amenity for an institution is one example. This website is utilized for security reasons. The gateway is typically located close to the main entrance. The portal height needs to be adjusted to allow cars to enter the area. A rope will be attached to the end of the portal, enabling the security officer to quickly close it by pulling it down. "What is the minimum required length of rope?" Trail walkers need to accomplish various tasks to overcome this challenge, such as measuring the distance between the base of the portal and the supporting post, the height of the supporting bar, and projecting the end of the portal to the ground. "Activity 2: Solve it using the principle of congruence." These activities, aided by digital technology, pertain to Mathematics, Engineering, and Science.



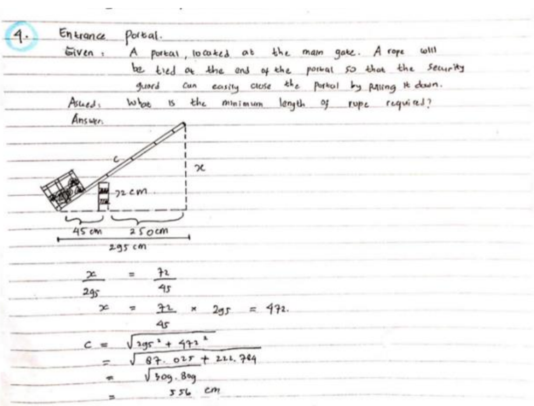


Figure 3. STEM Trail walkers follow the trail and solve the tasks.

STEM Trail walkers can access trails that are either openly publicized by trailblazers or closed trails that require a special code for entry. Once a path is chosen, the platform shows a map with numerous location pins representing the tasks along the route. Trail walkers use a map on the platform to go to the task they need to complete. Upon reaching the destination, you activate the pin, prompting a task associated with the object or event at that specific location to display. If the selected task and route do not need trail walkers to physically visit the location, they can be accessible remotely. Trail walkers are required to gather the essential data and information to solve a specific problem as it is a requirement outlined in the job description for activities and trails to be carried out on-site. The trail walker will obtain information and data regarding projects and routes that do not necessitate visiting the location.

Trailblazers create a set of questions or instructions for trail walkers to tackle the challenge. Once the problem is resolved and the solution is recorded in student worksheets, the outcomes are inputted into the website, and automatic feedback is given. Trail walkers can evaluate each task before proceeding to the next one, continuing this process until all tasks on the path have been completed and the challenge has been resolved. Trailblazers can view the results of trail walkers' actions once they sign onto the site.

92% of students actively participated in the activities and had positive experiences during the STEM Trails without encountering any obstacles, as indicated by the study results. We have examined the aspects that offered them joy and stimulated their interest in these activities through follow-up queries. 40% of questioned students cited engaging in outdoor activities as a factor influencing their preferences. 32% stressed the utilization of sophisticated technology, 28% advocated for the application of STEM in various settings, 20% highlighted collaborating with friends or teamwork, and 12% cited other reasons. 4% of interviewees expressed negative attitudes such as awful weather, exhaustion, shyness, difficulty, and technological challenges, while 0% reported feeling happy. This study examines the impact of this activity on student performance within the learning process. The study's results showed the average problem-solving scores for each task as follows: 88.80 for task 1, 87.40 for task 2, 88.40 for task 3, 87.00 for task 4, and 89.60 for task 5.

Discussion

Research shows that STEM Trails can help students gain the chance to cultivate 21st-century skills. These findings are consistent with the research conducted by Bergsten & Frejd (2019) and Kertil & Gurel (2016). STEM Trails combined theoretical principles with real-world implementations, as outlined by Holmlund et al. (2018). STEM Trails provide students with opportunities to engage in challenging and exciting mathematical explorations that significantly influence other disciplines. It corresponds with the argument put forth by Griffiths (2011). STEM Trails utilizes local resources to inspire learning through the STEM methodology. In line with Zheng et al., 2016, different locations and objects, especially those linked to culture, provide an opportunity to gain contextual knowledge in STEM fields. Landmarks in a region can serve as a foundation for incorporating the concept of STEM.

The STEM Trails Project entails creating projects centered around STEM-related topics that are connected to a particular site or object. The exercises are linked together to form an exploratory path, influenced by the idea of a math trail presented by Shoaf et al. (2004). This route enables the study of mathematics in the surrounding area. Cahyono (2018) mentioned that math trails can be developed using mobile applications that make use of GPS technology. This notion is not original. Combining outdoor math study, STEM Education methods, and mobile devices appears to be unique. Applying the STEM Education approach can help clarify mathematical concepts successfully when applied in real-world situations. This practice improves students' comprehension of the real-world use of mathematics, particularly in STEM fields, by integrating mobile technologies.

Research indicates that most kids participated in STEM Trails events and reported positive experiences. They were interested in outdoor sports, innovative technology, STEM applications, teamwork, and collaboration. Adverse sentiments included harsh weather conditions, fatigue, shyness, obstacles, and technical difficulties. The study also investigated the impact of STEM Trails on student academic performance. The study's results indicated that the students performed well.

Implication of Research

This study presents a novel approach to STEM education by integrating outdoor settings and digital technology. This innovative method enables interdisciplinary learning across multiple subjects and diverse environments, fostering the exchange of experiences and knowledge.

Limitation

The research on the implementation of this STEM Education approach is limited to the study of mathematical learning in a specific context and level. Further research is needed to explore its application in other subjects, as well as in different settings and areas.

CONCLUSION

The design of STEM Trails, the platform, and the STEM Education activities using Math Trails have all been finished. Individuals with an interest in science, technology, engineering, and mathematics are known as STEM Trailblazers in this program. They identify elements in their surroundings and design STEM pathways with appropriate assignments. Once the STEM Trail activities are completed, the outcomes are posted to a portal that STEM Trail participants can access and analyse using an application. Interdisciplinary learning involving science, engineering, technology, and mathematics can be achieved through STEM Trails, which are available in physical or virtual formats.

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