STREAM: A New Paradigm for STEM Education

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Abstract

This study proposes and explores "STREAM", a new concept that includes recreation to STEAM (Science, Technology, Engineering, Art, and Mathematics) to improve STEM education. Fifteen college students participated in a recreational activity created by the authors to teach the concept of Distributed Ledger; the students did not have prior knowledge on the subject. The students participated in a focus group discussion after the activity. The findings of this study revealed that eighty-percent of participants found the activity to be "helpful" or "extremely helpful" to understand the concept of Blockchain. Some of the distinctive themes from the participants' comments were that the activity was experiential, fun, interactive, and instructive. Therefore, it is concluded that STREAM should be used to enhance STEM education.

Introduction

Academics across the world have universally recognized the importance of a Science, Technology, Engineering, and Math (STEM)-oriented education system. Not only does engaging in STEM courses prepare students to enter a workforce inundated with specific knowledge, but it also teaches individuals how to apply their acquired skills in various contexts. Hence, students with relevant STEM educational skills, knowledge, and experiences are in great demand in both traditional STEM fields and other job sectors (Carnevale, Smith, & Melton, 2011; Rothwell, 2013). The employment in STEM fields has grown by 23% between 1993 and 2004, while the employment in non-STEM fields has grown by 17% during the same period. Furthermore, STEM fields encompass approximately 8.6 million jobs, representing 6.2% of the total employment of the U. S. in 2015 (U.S. Bureau of Labor Statistics, 2017). It is also projected that the number of STEM-related jobs will increase by 23% between 2015 and 2028 (U.S. Bureau of Labor Statistics, 2017).

Even though the importance of STEM education has been repeatedly emphasized, statistics showed that the U.S. STEM education system has not been viable. According to the National Center for Education Statistics (2007), American students' science and mathematics proficiency was ranked 22nd and 31st respectively in the world. More recently, the results of a cross-national academic achievement test among 15-year-old children by the Programme for International Student Assessment (PISA) revealed that among 71 countries, the U.S. was ranked 38th and 24th in math and science literacy, respectively. Furthermore, among the 35 OECD (Organization for Economic Cooperation and Development) member nations, the U.S. ranked 19th in science and 30th in math (Pew Research Center, 2017). A recent survey also revealed that nearly three-quarters (73%) of the U.S. adults stated that the quality of the U.S. STEM education for K-12 is average or below average, while only 25% indicated that it is better than average of other developed countries. Furthermore, 87% of the U.S. adults with postgraduate degrees in STEM responded that the K-12 STEM education in the U.S. is no better than that of other developed countries, and 51% of them rated the U.S. K-12 STEM education worse than that of other countries (Pew Research Center, 2017). In higher education, 63% of U.S. adults rated the U.S. STEM education as average or below average, and 60% rated the U.S. graduate STEM education as average or below average, compared with other developed countries. (Pew Research Center, 2017).

Because students from the U.S. lag behind many other advanced industrial countries in STEM proficiency, the U. S. government has launched a variety of programs and campaigns to improve STEM proficiency. In 2009, the U.S. government launched the "Educate to Innovate" campaign. The campaign's intent was to bring together the federal government and other sectors, such as non-profit and private organizations and research communities, to enhance STEM knowledge, to improve education quality, and to increase career opportunities. The campaign has provided financial and in-kind support for STEM education programs across the country. In 2011, the Committee on STEM (CoSTEM) has been established with 13 government agencies and facilitated a comprehensive national strategy. The committee has developed and implemented a 5-year STEM education plan for the following five areas: 1) preschool through 12th grade education; 2) undergraduate education; 3) education for historically underrepresented groups; 4) graduate education; and 5) public engagement. The plan includes detailed objectives and approaches to improve each of the 5 areas. More recently, the Department of Education, alongside the American Institutes for Research (AIR), organized a series of workshops in the field of STEM education. Individuals with a wide range of expertise in STEM education, including K-12 teachers, college professors, researchers from private organizations, and education consultants, released a report called "STEM 2026: A Vision for Innovation in STEM Education." STEM 2026 integrates the key observations and results of the workshops and outlines the experts' recommendations for the future STEM education.

In order to fulfill the requirements of governmental programs and campaigns, educators and researchers have sought a variety of educational methods to improve K-12 STEM education. One of the auspicious approaches includes interdisciplinary collaborations. STEM learning and teaching experiences can be enhanced through integrated programs or activities among multiple disciplines, particularly between a STEM discipline and a non-STEM discipline (STEM 2026; National Academies Press, 2014). The STEM 2026 report includes educational experiences through interdisciplinary approaches as one of the major components to improve STEM proficiency. As in the report, interdisciplinary approaches to teaching and learning between STEM disciplines and non-STEM disciplines can be more effective than simple traditional approaches because they will provide opportunities for children to explore STEM concepts in more interactive and engaging ways.

Literature Review

Effects of arts on academic performance

The effects of arts on academic performance have been well documented (Americans for the Arts, 2017; Foley, 2017; Sandmire, Gorham, Rankin, & Grimm, 2012). Eisner (2002), a well-known art educator, posited that arts can make three distinctive contributions to intellectual development. These three contributions pertain to the personal experience that the arts create, the meaning that the arts generate, and the development of thoughts that the arts foster. In other words, the unique experiences and meaningful connections that people make with arts will help develop critical forms of thinking. Multiple studies and programs have been initiated to investigate the relationship between the arts and academic performance. The President's Committee on Arts and Humanities (2015)

reported that implementing the "Turnaround Arts School" program for eight public schools with students predominantly from low-income families across the U.S. produced a noticeable improvement in academic achievement and overall performance. More specifically, on average, the 8 schools demonstrated an improvement of approximately 23% in math proficiency between 2011 and 2014. In addition, one school improved its math proficiency rate by 120%. The findings also revealed that the eight schools with the "Turnaround Arts Program" showed a consistent improvement in attendance; in particular, 4 out of 8 schools demonstrated noticeable improvement in attendance.

Another study conducted by Scripp, Burnaford, Vazquez, Paradis, and Sienkiewicz (2013) reported similar results. Through a partnership with Chicago Arts Partnership in Education (CAPE), Partnership in Arts Integration Research (PAIR) completed a 4-year study, funded by the U.S. Department of Education, to investigate the impact of art education on students' academic performance. Six schools in different school districts were selected as an experimental group and were assigned to implement arts-integrated instruction. These schools were compared to six other schools that did not implement the arts-integrated instruction. Key findings of the study indicated that 85% of the students in the schools with arts-integrated instruction met or exceeded average standardized test scores of Illinois Standard Achievement Test (ISAT), while only 59% of the students in schools without arts-integrated instruction met or exceeded ISAT scores. Furthermore, the results of the study revealed that arts-integrated instruction is particularly effective in improving the academics of low-performing students. The ISAT scores increased by 22% and 10% for low-performing students and for high performing students, respectively. The report concluded that arts-integrated instruction had significant impacts on students' academic achievements.

In 2009, the Pittsburgh Public School Council created the "Greater Arts Integration Initiative (GAIN)", a collaboration between Pittsburgh's public school districts and Manchester Craftsmen's Guild (MCG), to investigate the effectiveness of art-integrated curriculum on students' academic performance. School district teachers worked with MCG's visual artists, creating specially-designed arts-integrated lessons for math, science, and world culture classes. The results of the study showed that students in schools involved in GAIN have significantly higher academic achievements. More specifically, students in schools with GAIN who took the Pennsylvania State Standard Assessment had math and reading scores that were 23.6% and 20.8% higher, respectively, than those who were in schools without GAIN.

In addition to enhancing academic achievement, studies have reported that arts education can contribute to other areas of students' classroom performance. According to the results of a 3-year national study, Catterall (1995) reported that implementing "Different Ways of Knowing Program", which incorporated visual and performing arts with other curriculum subjects, produced significant positive effects on students' learning engagement and motivation. The study concluded that interdisciplinary teaching methods should be encouraged to improve student performance. Chung and Kim (2010) reported similar results, showing that music education helps elementary students exhibit better behavior within the classroom, such as assertiveness, cooperation, and self-control.

Because arts can positively impact student performance, STEM educators and art educators have worked together to develop an interdisciplinary teaching method, called STEAM (Science, Technology, Engineering, Arts, and Mathematics), to increase STEM proficiency.

Development of STEAM

STEAM, created by the Rhode Island School of Design (RISD), is an educational initiative that combines the arts into the STEM framework. Through STEAM, educators can apply project-based instructions for all five disciplines (science, technology, engineering, arts, and math), which promotes an interactive learning environment in which all students can participate and contribute. The goal of STEM to STEAM is to incorporate elements of art to STEM concepts to promote interest in STEM. To accomplish the goal, RISD lists the followings as primary objectives: (1) to transform research policy to place Art + Design at the center of STEM, (2) to encourage the integration of Art + Design in K-20 education, and (3) influence employers to hire artists and designers to drive innovation.

Traditional STEM education mainly focuses on developing convergent (problem-solving) thinking skills, whereas art education emphasizes divergent (creative) thinking skills (Land, 2013). Convergent skills follow one specific process to come to a solution for a problem, while divergent skills aim at exploring many possible solutions to a problem. Hence, divergent thinking skills are said to foster creativity (Kang, Jang, & Kim, 2013; Madden, Baxter, Beauchamp, Bouchard, Habermas, Huff, & Plague, 2013). Developing holistic teaching methods can improve both convergent and divergent thinking skills; by bringing diversity and variety, it will leverage the dynamic synergy between disciplines within the STEM field.

Over the past several years, several schools and school districts have adopted the "STEM to STEAM" approach to improving both divergent and convergent skills. For example, math teachers at Andover High School teach the basic concepts of geometry through the lens of art. Students go to a local art museum and examine the ways geometric concepts and artistic perspectives are inherently related (Stack, 2015). The State University of New York at Potsdam, partnered with Lockheed Martin, has initiated an interdisciplinary program by combining STEM courses with arts and humanities with the intention to produce professionals with versatile skillsets (Madden, et al., 2013).

STREAM (STEAM + Recreation)

Recreation, which involves physical activity, is another area that has received attention from researchers who are interested in integrating different aspects of education in order to improve student performance. Research has found that recreational physical activity not only improves physical fitness but also psychological health and cognitive function (Donnelly, Hillman, Castelli, Etnier, Lee, Tomporowski, Lambourne, & Szabo-Reed, 2016; Lees & Hopkins, 2013; Reiner, Niermann, Jekauc, & Woll, 2013). Those who participate in recreational activity are able to change both the functional and organizational compositions of their brains, resulting in an improvement in their cognitive ability and mental health (Lin & Kuo, 2013). According to a study conducted by Donnelly et al. (2016), recreational physical activity benefits the parts of the brain that govern cognitive functioning. More specifically, recreational physical activity enhances both metabolism and cardiorespiratory fitness and stimulates neurochemicals, all of which affect the central nervous system, central biomarkers, and peripheral biomarkers (Tang, Xia, Wagner, & Breen, 2010, Voss, Vivar, Kramer, & van Praag, 2013). These three mechanisms are responsible for cognitive functioning (Voss, et al., 2013). Cognitive abilities are conducive to developing skills in critical thinking, logical reasoning, and problem-solving, all of which are essential for STEM education (Berkowitz & Stern, 2018). Students with higher cognitive abilities tend to acquire knowledge and skills more effectively and swiftly than those with lower cognitive ability (Gottfredson & Deary, 2004). In addition, research has consistently shown that an individual's cognitive ability tends to correspond with achievement; therefore, there is a positive correlation between participation in recreational physical activity and academic achievement, particularly in STEM fields (Mura, Vellante, Nardi, Machado, & Carta, 2015; Watson, Timperio, Brown, & Hesketh, 2017). Similarly, the result of Aaltonen, Latvala, Rose, Kujala, Kaprio, and Silverntoinen's study (2015) on the relationship between participation in leisure-time physical activity and academic achievement revealed that there is a positive relationship between recreational physical activity and academic performance. Lees and Hopkins (2013) investigated the effects of aerobic physical activity on cognitive and psychosocial functions and academic achievement. The authors found that participating in such activities positively contributes to predicting the academic achievement after students' demographic variables, such as gender, ethnicity, grade level, parental income level, etc. were statistically controlled. Cooper, Valentine, Nye, and Lindsay (1999) also investigated whether variables in student backgrounds had an effect on the relationship between participation in recreational activity and academic success. The researchers found that participation in afterschool recreational programs significantly influences academic success.

Despite previous studies have found that recreational activity can benefit cognitive functioning and academic achievement, no empirical studies have been conducted

regarding the use of recreational activity as an effective method to teach complicated STEM concepts. In order to fulfill such a need, the researchers propose a new concept--"STREAM"--which integrates the recreation into STEAM-based teaching methods. The purpose of the current study is to examine if STREAM, or the application of recreational activity in a classroom environment, is an effective method to teach STEM concepts. Specifically, this study is designed to answer the following questions: (1) Is the incorporation of Recreation into STEM effective for conveying STEM concepts to students? (2) What are some distinctive comments and themes derived from the participants' perceptions of STREAM?, and (3) What aspects of activity do help the participants understand the basic concept of "Blockchain"?

Method

The operational definition of the recreational activity for this research encompasses any interactive or experiential activity that promotes both physical and psychological well-being for participants.

The STEM concept that the researchers chose was the concept of "Distributed (or Shared) Ledger", which is one of the key concepts in Blockchain technology. The concept of Blockchain, especially "Distributed Ledger," has become one of the most important, albeit very complicated, concepts in many industries, including the computer, security, banking, and retail industries. Distributed Ledger is "a chronological chain of 'blocks' where each block contains a record of valid network activity since the last block was added to the chain" (Abeyratne & Monfared, 2016, p.2). The researchers created a recreational activity called "Who is the cheater?" which mimics supply chain management. The activity consisted of two parts; first, the participants observed an activity that depicted a normal one-way distribution channel, including a sender, intermediaries, and a receiver. In the activity, an intermediary hid the original item from the sender and sent a different, less valuable item to the receiver. After watching the activity, participants engaged in an activity that illustrated the "Distributed Ledger" concept. Participants played as multiple institutions on a peer-to-peer network. Each participant, as an approved peer-to-peer network, verified, coded, validated, and stored the transactions to ensure security. Further, the participants shared their own information and determined whether each Blockchain was valid or not through a simple consensus algorithm, which alerted the participants of undesirable transactions.

In order to address the research objectives and answer the research questions, the researchers used a qualitative research design of focus group discussion as a means of data collection. In focus group discussions, participants interact with other people and exchange anecdotes, commenting on other's opinions and views (Kitzinger, 1995). Therefore, the focus group methodology is particularly effective in gaining profound knowledge about certain issues and phenomena (Kitzinger, 1995).

The participants in the focus group discussions were 15 college students from different academic fields who attended a research symposium on emerging information technology. Among the 15 participants, seven were male and five were female. Focus group discussion questions were methodologically developed by the researchers and reviewed by experts to ensure validity and reliability. The questions were primarily aimed at assessing the effectiveness of the use of recreational activity to understand the concepts of Blockchain. The researchers addressed the following questions: Do you think the activity was effective to understand basic concepts of Blockchain? What aspects of activity do help you understand the basic concepts Blockchain? What are the favorite and least favorite aspects of the activity (any suggestions to make the activity better)?

The focus group discussions lasted approximately 40 minutes, and one of the authors facilitated group discussions as a moderator. The discussions were video-recorded, and these recordings were transcribed verbatim for data analysis. More specifically, the authors transcribed the recording and generated seven pages of written dialogue. Once the transcription process was complete, the authors watched the recordings again in order to check the accuracy of the transcription. It took approximately 6 hours to transcribe the recordings.

Results and Discussions

The analysis of the transcriptiorevealed that the majority of participants stated that participating in the recreational activity aided them in understanding the concept of Distributed Ledger in Blockchain. More specifically, 80% (N = 12) of the participants stated that the activity in which they participated was "effective", and 30% (N = 5) of the participants indicated that the activity was "extremely helpful". To analyze the sentiments of the participants further, the researchers scrutinized the participants' dialogues and comments.

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The findings of this study support the idea that implementing a recreational activity to teach STEM concepts can be very effective. As shown in Table 1, some of the distinctive themes that were derived from the transcription of the recording are that the activity is: experiential, fun, interactive, and instructive. Table 1 presents a summary of themes and comments derived from the focus group

Themes	Comments
Experiential	The activity was particularly effective because we can actually experience how the concept works. The experiential learning elements help me understand the concept more easily The best thing about the activity was that we were able to experience the whole process
Fun	STEM education should be using fun activities, like the activity we saw today, especially for kids The activity was very fun and effective to draw attention Unlike a traditional lecture, the activity was very fun and easy to understand yet very instructive
Instructive	The activity was very instructive and well created to convey the key elements of the concept A step-by-step process was very visible and easy to follow
Interactivity	An interactive approach demonstrated the concepts well and fostered understanding the concepts The interactive aspects of the activity were extremely helpful to understand the concepts

Table 1. Themes and comments from focus group discussion participants

discussion participants. Previous research consistently reported the importance of these themes in education. More specifically, it is well-documented that experiential learning can significantly enhance the learning process and outcome (Kolb & Kolb, 2009; Kolb, 1984). Experiential learning is defined as "the process whereby knowledge is created through the formation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb, 1984, p. 41). Simply put, experiential learning can be referred to as "learning by doing" (Race, 2002).

Experiential learning is active rather than passive, hence, it is crucial for learners to be actively engaged in the learning activities. In a similar manner to experiential learning, active and interactive learning have received considerable attention from educators. Revell and Wainwright (2009) define active learning as "the idea that students are actively engaged in the learning process, rather than passively absorbing lectures" (p. 210). Kolb (1984) posited that learning occurs best when students are encouraged to interact and experience as both actors and actors (Revell & Wainwright, 2009). Spronken-Smith (2005) also supported the notion by stating that students are more receptive towards an active and experiential learning approach as opposed to traditional lectures because of the interactive and hands-on aspects that are involved in such education. Furthermore, Newble and Cannon (1995) found through their empirical research that attention levels last no longer than 20 minutes of the presentation, even in a very interesting lecture. Hence, from a pedagogical viewpoint, participation and interactivity are two major components in enhancing active and experiential learning.

Another major theme derived from the participants' comments is fun. There is no doubt that implementing an effective teaching method is critical in education because it can generate either a positive or a negative learning experience. Because it is capable of creating a more interactive and engaging learning environment, fun is one of the most powerful and effective pedagogical elements in education (Chasrky & Ressler, 2011). People who practiced tasks under enjoyable and interactive circumstances have shown significantly greater improvement in learning and performance than those who participate in a formal environment (McInnes, Howard, Miles, & Crowley, 2009). Similarly, the Bureau of Education and Cultural Affairs, U.S Department of State (2016) reported that students are more willing to partake and engage in class when teachers integrate enjoyable activities into their lesson plans, stating that having fun will boost their confidence and motivation without the fear of committing mistakes (McInnes, Howard, Miles, & Crowley, 2009). Furthermore, people retain information better when the learning coincides with positive emotions (e.g. fun, joy, etc.), while negative emotions (stress, boredom, anxiety, etc.) interfere with learning (Christianson, 1992; Willis, 2007).

Additionally, neuroscientists revealed that "when students are comfortable and feel minimal stress, information flows more freely through the affective filter in the amygdala and they achieve higher recognition, make connections, and experience "aha" moments." (Willis, 2007). Thus, they concluded that fun is a key factor for a high-achieving classroom, and learning often stops when fun stops (Jensen, 2015; Willis, 2007).

Conclusion

STEM education is an essential part of the U.S. education system. The U.S. government has developed numerous programs and has invested a substantial amount of resources to improve STEM education. However, statistics show that the outcomes have not improved. The authors propose a new and innovative approach, "STREAM (STEM+Arts+Recreation)", to teach STEM concepts more effectively.

STREAM employs unique aspects of arts and recreation to supplement STEM education. As stated previously, educators integrated unique aspects of arts, such as creative thinking, into traditional STEM education, which mainly focuses on developing convergent (problem-solving) skills. Alongside arts, recreational activities not only improves physical fitness but also psychological health and cognitive function. Such a combination can generate synergic effects in STEM education. The findings of this study support that recreational activity can be used as an effective tool to teach STEM concepts.

Teachers and researchers should consider using a recreational activity that includes the aforementioned elements to teach STEM concepts more effectively. For example, STEM educators may collaborate with recreation specialists to create unique recreational activities that can facilitate learning STEM concepts.

Limitations and Recommendations

It should be noted that this study is not without limitations.

First, the participants for this study were college students who attended a research symposium on emerging information technology. In order to produce more convincing and generalized results, it is recommended that future studies use more diverse groups from heterogeneous demographic backgrounds, as the demographic characteristics may influence the learning process.

Second, different statistical approaches with a larger sample size should be considered. This study used a qualitative approach to measure the effectiveness of STREAM, however, there is a need for quantitative assessment of recreational activity on the efficiency of teaching STEM concepts.

Finally, this study used a recreational activity called, "Who's the cheater?", which was created by the authors. It might be intriguing to examine and compare how different types of recreational activities will affect learning outcomes because learning can be greatly influenced by personal experiences and interactions.

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