Adopting creative pedagogy for STEAM education in technology enhanced environments

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Abstract

Employing an arts-integrated Science, Technology, Engineering, and Mathematics (STEAM) approach to education benefits the students by triggering creativity and innovative thinking. By teaching through STEAM, the teachers can better make connections between subjects and students understand the interconnectedness of those fields. Introducing creativity through the arts when teaching complex topics aids students in becoming creators of their knowledge, as they can explore ways to make connections between disciplines and obtain specific information by taking initiatives, individually or collaboratively. The idea of bringing together the creative approaches of learning, and taking ownership of the learning process initially requires a creative pedagogical approach. This approach of teaching to be creative is claimed to be one of the most successful ways of learning [1]. However, integrating creative pedagogy into technology became a necessity as technological advancements have been transforming the teaching and learning experiences. Intersecting the creative pedagogy (the arts in STEAM) and technology-enhanced learning establishes new outlets of interdisciplinary teaching and learning. The recent global COVID-19 pandemic has caused an abrupt transition to distance education that required the integration of technology and digital platforms into everyday teaching because teaching and learning have started to happen in online environments. Such transitions have inspired educators to notice that they could adopt digital interventions in their classrooms. This educational design research aims to further understand and develop a set of digital design principles that aims to bring together interdisciplinary topics of STEAM by utilizing arts. To illustrate and demonstrate different levels of uses of these design principles, a multi-layered digital structure will be built. The design process is planned to be co-created by high school teachers with the consideration of how we could help and support students with diverse backgrounds and interests, and teachers with different technical and artistic competencies. The expected result is theorization and the utilization of the design principles in integrating interdisciplinary subjects through arts.

Keywords [1]

Creative pedagogies, technology-enhanced learning, STEAM education, distance education, and interdisciplinary.

1. Introduction

STEAM (Science, Technology, Engineering, Arts, and Mathematics) is an acceleratingly popular educational approach that had been first idealized in the Americans for the Arts-National Policy Roundtable in 2007 to incentivize students to obtain skills linked to STEM (Science, Technology, Engineering, and Mathematics) fields [2]. Arts guide a larger number of students into understanding interdisciplinary connections through abstract ideas, and use those concepts to solve real-life problems [3]. Including arts in

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the STEM curriculums help the students to build necessary skills for their careers in the 21st century [4, 5]. As Colucci-Gray et al. [6] states: combining scientific practices with design, innovation, and artistic expressions is "integral to the process of thinking." (p.2). Platz [7] stresses that student who practice In an arts-domain perform better in their STEM courses because they feel interested and motivated about the new information. However, literature shows that STEAM practices vary vastly, with no coherent description or methods to align with the learning goals. In their extensive literature review, Perignat and Katz-Buonincontro [2] have found that STEAM has been employed as a "pedagogical tool" to integrate arts into STEM fields (p. 38). Learning through arts is stressed to be easing the long-term retention for students [8] motivating them to be creative and innovative, and supporting their cognitive involvement by guiding them to construct their knowledge. What Kahu [9] identified to be major agents of student engagement are also linked to some expected outcomes of learning through arts: behavior, cognitive, affection. Behavior is about positivity towards the subject and initiation of learning such as researching, asking questions during lessons, etc. The cognitive aspect is about self-regulation where students plan and execute their long-term learning goals. The affection aspect is about students' emotions and interest in the task. This research follows a similar approach towards student engagement, however, it differentiates by including a fourth agent about the instruction and the environment, that corresponds to Fredricks et al. 's [10] conceptualization. Although we can use these elements to identify student engagement and use this awareness to improve and shape the intervention accordingly, it will remain to be a construct that only aims to regulate learning in a way to engage students.

Engaging students does not necessarily require the learning to occur, letting aside achieving successful learning. However, when an immediate change is due, like in the COVID-19 pandemic outbreak, retaining student involvement and engagement to promote learning becomes a challenge. Once schools all around the globe have transformed to distance education where all the teaching activities take place online and where every participant joins from another location, disputes have arisen while transforming the teaching material and the teaching approaches. To overcome these issues, school administrations and the teachers have tried multiple methods of online-friendly transformations that include digitizing the content (i.e. scanning worksheets, taking photos of the visual teaching materials, etc.), scheduling virtual classes on video teleconferencing software (to replace real-classes, by utilizing Zoom, Google Meets, Skype, etc.) [11], and facilitation of quizzes through online platforms while asking the students to keep their camera on to ensure they do not cheat. Although they seem to be feasible solutions, none of them are considered efficient in the long-term adaptation [10, 11]. Regardless of their sufficiency, distance education is turning into a preferable method of instruction.

With the rise in the use of distance learning, students experience motivational problems [12] due to learning from a distance as it does not involve as much interaction and requires much self-regulation and independence. Motivational correction is considered to be easier in classroom settings as the teachers have the opportunity to observe and intervene with the students directly [12], but the integrity of student motivation and engagement becomes a challenge in partially digital and innovative teaching content. By this, the partially digital teaching contents address the digitized versions of blueprint teaching materials and classroom approaches. In the pre-COVID-19 world, education technologies were developing swiftly, and much research had been undertaken about implementing technological solutions into educational problems such as aiding student engagement, measuring and tracking student participation, and personalizing the learning outcomes. Technology-enhanced environments and learning strategies have supported and made room for such innovation to happen, but lacked practicality [13] due to limited dissemination. Technology-enhanced environments allow teachers and students to integrate the course format fully into online distance learning or in-classroom according to their needs, and by doing so, achieving an immersive learning experience that promotes engagement and motivation in students. Technology-enhanced environments are settings that are used by the instructors, facilitators, teachers, and learners for helping students to obtain knowledge and skills through the means of technological

resources, and tools [13, 14]. The term technology-enhanced environments is used to address both online distance learning platforms and the actual classrooms that are equipped with technology.

The COVID-19-caused rapid transition to online distance learning has illustrated where and how technology-enhanced learning was needed and could be adopted. However, such awareness does not tell much about the students' side of the learning experience, that is, the student's motivation, engagement, curiosity, and learning. As it has been stated, students struggle in remaining motivated during distance learning [15] which can potentially influence their engagement and learning. However, introducing an arts-related activity in lesson plans can help improve students' motivation and engagement. Especially considering the difficulty in keeping the students' focus and engagement in STEM classes, it becomes vital to integrate an artistic mediatory in the teaching approach because artistic expressions can support students in becoming interested in the knowledge they acquire [7, 8]. Dewey [16] has suggested that arts education is one of the core parts of the curriculum because arts help "develop creativity, self-expression, and an appreciation of the expression of others." [17, p.136]. Therefore, it is necessary to apply STEAM approaches with an artistic focus on technology-enhanced environments. However, such applications do not function well in a short-term intervention [15] as it causes a disrupted cognitive fulfillment for not allowing enough time to build creativity and solution-orientation. Instead, the students will focus on logic-based explanations that explicitly aim to describe the current state of a problem or phenomena [8]. Such an approach does not support trial-error during learning which negatively impacts the self-efficacy of students. Therefore, the teachers need to be equipped with tools and competencies that will enable them to design and integrate artistic activities on technology-enhanced environments.

The challenge resides in transforming the pedagogical approach, as solely shifting the teaching materials is not sufficient and sustainable action towards improving student engagement. Therefore, we aim to adopt a pedagogical approach that can stimulate student interaction, creativity, willingness, and engagement altogether to provide successful learning. Bringing together all these desirable attributes seems feasible with a creative pedagogical direction. Although STEAM suggests interdisciplinary learning, it seems that arts are always used as a method to teach STEM subjects and not as the target subject to be taught, making it hard to place the arts among the others as an equal field [18]. Moreover, the diverse and clashing practices of STEAM can hinder inclusion of creativity, however, the lack of research in the approaches of creative pedagogies can be a challenging step in determining the benefit of teaching creativity [2, 19]. To overcome this challenge and address the "A" in STEAM education, this research will refer to creative pedagogy. The term refers to a sum of teaching through artistic methods in this research. Lin [20] addresses creative pedagogy as an intersection of teaching for creativity, learning creatively, and teaching creatively which also integrates both the teachers' and the students' role of learning creatively. Although having the role of learner can initiate an exhaustive philosophical discussion on learning to learn and the role of the teacher and the student in the classroom, Aleinikov [1] describes creative pedagogy in a more practical sense; as a way to initiate life success by introducing the learners to create their knowledge, to think out-of-the-box (creativity skills), and to be innovative.

Creative pedagogies are an inherent approach to teaching creatively to guide students in taking ownership and responsibility of their learning in all study fields. The teacher fosters the role of the tutor who structures the courses and supports students to build self-efficacy to overcome real-life problems, and scientific inquiries [8]. By instrumentalizing arts to teach STEM creatively, the teachers can help their students to understand how diverse-looking disciplines interconnect. The creativity aspect has been influenced by the introduction of educational technologies into everyday learning. The combination of both has accelerated the process of involving technologies in learning to keep the students engaged and make their learning success. With the current global pandemic, in-classroom education has been transitioned to distance education all around the world. This shift caused many teachers to struggle with the new structure of teaching and the needed technological competencies, students faced hardship on maintaining interest and remaining engaged with course material. Therefore, we

need to instrumentalize more of the digital tools or approaches that are inclusive of distance education. To fulfill such potential, and establish new aspects to the current pedagogical approaches, it becomes a necessity to challenge the traditional sense of creativity and education by rethinking and redesigning STEAM education scenarios that could be applied to distance or contact education. In the intersection of creative pedagogies and TEL, incentives, and interventions relating to technological creative teaching approaches stand. However, the current tools and interventions need some development to bring these aspects together.

This research accepts the constructivist approach and integrates pragmatic reasoning to it to develop a set of design principles to be employed for teaching interdisciplinary concepts through arts digitally, and to design an intervention that demonstrates methods to utilize those design principles.

2. Methodology

The aim of this research is to propose a framework of design principles to integrate arts and one or multiple STEM subjects by demonstrating a set of digital activities on a to-be-designed digital construct. This aim is portrayed by the initial question of this research: *what attributes are effective and sustainable in a digital design that aims to educate upper secondary school students on STEM subjects through arts?* To address that big question and to achieve the research purpose, the following overarching questions will be investigated:

1. How do teachers and students combine information that originates in different knowledge domains of STEAM?
2. What are the current awareness, practices, and challenges of teaching interdisciplinary STEAM subjects digitally in upper secondary schools in Estonia?
3. What are the characteristics of a well-functioning and engaging digital artistic intervention for the purpose of integrating multidisciplinary learning strategies?
4. What types of characteristics do the digital artistic interventions should constitute to stimulate students' interest and engagement on a complex interdisciplinary STEM topic?

To accommodate the layered structure of the research questions, and to generate key characteristics of interdisciplinary design principles of STEAM, this research will adopt a mixed-method design-based approach. There are four major phases of the design research to compose the final outcome of this project, namely: (1) analysis, (2) development, (3) evaluation and revision, and (4) dissemination. Each phase constitutes iterative processes to enable rebuilding, and amending the prototype and the included design principles. The research design is an altered combination of McKenney and Reeves' [21], and Plomp's [22] educational design research models. The interaction between phases and the cyclical research model of this research is illustrated in Figure 1.

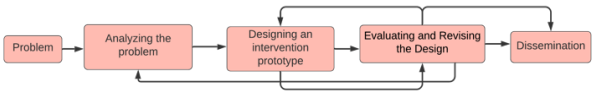

Figure 1: The design-based research model adapted for this research

The preliminary analysis phase consists of (1) a detailed literature review to identify the current digital practices of STEAM education, and those activities' advantages and drawbacks, (2) an analysis of the current awareness, practice, competence, and approach of upper secondary school teachers (of STEAM fields) towards teaching STEM subjects through arts (creative pedagogy) and on digital platforms. Only one data collection is intended for this stage to gather information on the 2nd factor of this phase. The data will be collected by the means of survey questionnaires with close-ended questions, and semi-structured interviews with teachers. The teachers will be acknowledged about the further proceedings of this research and asked to join for the other phases. This direct invitation would be one of the methods to employ participants. After obtaining descriptive results from the first phase, the development stage will commence in accordance with the findings.

The development and the evaluation phases are strongly interconnected and are planned to have at least three cycles to mature

the intervention and to achieve the intended outcomes. The teachers will be employed through the network of other PhD candidates and colleagues working on technology-enhanced learning and educational technologies at Tallinn University. The teachers will be partners in this research as they will be responsible for participating in co-creation workshops to brainstorm and develop the intervention idea. Upon developing a prototype, the teachers will try it in their classroom, observe their students for engagement and behavioral changes. They will include their feedback and in-class activity assessments to identify whether the tool had been used with intended purposes and whether it helped to teach interconnected STEAM subjects. According to the evaluation reports from the teachers, and data analysis, the intervention will be revised accordingly. During this process, it becomes vital to understand the students' perspective of interacting with a digital tool aiming to teach STEM subjects with the help of the arts. To gain insight, the students will be asked to fill in a pre-questionnaire about their expectations, and their awareness of integrating arts with other STEAM subjects. Then, they will be asked to keep a record of their experience in an activity log; so it will enable the teachers and the researcher to classify whether there were any unintended uses. The data obtained from the teachers and the students will be analyzed collectively for identifying mismatches between the observation of the teacher and the self-reports of the students.

By utilizing the intervention and gathering insightful data from both the teachers and the students, this research can become aware of what design principles are commonly used to integrate interdisciplinary subjects. Such design principles are necessary to determine a framework for creating a digital intervention for teaching STEAM interdisciplinary by purposefully utilizing the arts.

The intended intervention is a digital structure that resembles a bookcase that has developmental archival storage. The main objective is to combine the same set of design principles in each level to illustrate the uses among simplistic to complex interdisciplinary design ideas. The first level will consist of ideas where the teachers could select certain expected outcomes or topics to integrate, it functions in a way that the teachers will determine their needs and request a ignite to pursue that idea. The second layer will suggest the teachers incorporate some additional tasks onto their selection, and by doing so obtain extra learning objectives as a result. These two layers will be co-developed by the researcher and the teachers. These two layers will list down certain materials that are accessible through a hyperlink. This way, the teachers could assign students with certain tasks, and send them the link to access the materials without needing to hand in task maps, materials, etc.

The third layer will introduce arts (fine arts, music, plastic arts, literary arts) as parts of the integration. For instance, students are given Leonardo da Vinci's drawings and paintings in a class that aims to teach certain mathematical phenomenon. The last layer builds upon the third one by allowing users to download activities, and upload their newly created artistic expression projects that aim to teach STEM subjects. New creations are an updated version of the activities on the third level or transformed versions of those tasks. Such a complex construct will predicate on the same design principles which will demonstrate the convenience of adopting creative pedagogy on digital tools. As the base principles remain the same for each layer of the intervention, it is intended to welcome and encourage teachers of different competence levels.

Although the ambitious goal is to integrate all disciplines of STEAM (in different combinations or altogether) in the digital structure, such a plan becomes unrealistic and unapproachable due to time and budget constraints. Therefore, this project will determine one of the non-arts STEAM fields and focus on that field during this research. However, that selection will be made upon meeting with teachers and gathering more insight through data. The intervention will aim to:

- Demonstrate the design principles of how to bring together different STEAM disciplines by purposefully utilizing arts.
- Showcase how the design principles could be successfully implemented in different levels of digital structures and designs.
- Support student engagement and interest with creative interdisciplinary

tasks on the developed digital structure.

- Overcome the technology-competence barrier of the teachers, and encourage them to take ownership and be creative in their profession.
- Help the teachers to explore ways for guiding their students through complex interdisciplinary relationships.

2.1. Ethical consideration, limitations, and expected responsibility distribution

Language barrier resides to be the primary limitation of this research. I do not speak Estonian and need to work with students who can communicate in English, or ask the teachers to translate the conversations/data. Alternatively, working with a MA Educational Sciences student during data collection can help me overcome this challenge.

As I am a new-starter of coding, it may be challenging to produce the intervention by myself or with the sole support of the teachers, and I may need to work side by side with a programmer. However, as the intervention is not going to be a mobile application that requires more complexity, this limitation will be overcome by using online platforms to generate content that is to be utilized as a demonstrative and functioning design.

Teachers will be in direct contact with the students, and as some students might feel obliged to comply with the teacher's requests or instructions, this may arise power-related problems. Another power issue could reside in the relationship between the teacher and the researcher. We can overcome the latter by assigning the teachers to be action researchers alongside being co-creators. The teachers will be responsible for tracking their students' progress, interest, and success. Alongside the interventions' influence on the students, the teachers will be responsible to note any positive (the intervention works in favor of students' learning, and teachers' ability to use it), and negative (misuse of the intervention- if possible, lacking function and purpose) influence of the intervention. The teachers will be asked to gather these observations, and notes together to share their experience with the researcher. We will ask students to provide us with individual and group feedback to share their opinion of the intervention, and if they think this new tool works for them with the reasoning behind them. Then, we will ask students to tell us how we could improve this intervention that they would prefer using it.

The researcher is responsible for (1) categorizing and analyzing all data including the student feedback, (2) co-creating the intervention with the teacher, (3) noticing the patterns in the design that may be challenging, and (4) identifying design principles in the process of development. The teachers will be responsible for (1) co-creating the design, (2) working as action researchers who are willing to improve their professional skills, (3) collecting data from the students, and (4) taking observation notes and writing feedback during their classes.

2.2. Expected outcome and significance

This research starts with a goal to identify the characteristics of the effective implementation of arts subjects into STEM subjects on digital environments and platforms by producing a curated medium through analyzing the existing approaches and practices alongside this research. It is expected to establish a set of digital design principles for integrating arts into teaching, and a reliable tool that helps teachers to teach STEM subjects through arts while creating a basis to encourage further research adopting the design principles.

The intervention can be employed by higher education institutions in the future, especially for teaching engineering students to foster creativity, innovative thinking, and communication in their professional life. The intermediary digital structure is planned to be a demonstration of how such design principles could be utilized and employed. By doing so, I aim to provide an explanatory and prescriptive theory that can guide other research in a similar field, especially investigating the interconnections of STEAM subjects, and the methods of teaching and learning these subjects in alignment with their interconnectivity. The tool and the design principles behind it will be used to elaborate and clarify some of the

fuzziness in the practice and theory about TEL-empowered STEAM education.

The arts in STEAM are used solely for the purpose to be a way to teaching STEM subjects, making the arts-related studies considered insignificant for both the learner and the teacher. However, it has been evident that art studies alongside or through STEM subjects provide ground for growth by integrating 21st-century skills and inclusivity. Therefore, this research will focus on developing a framework of design principles for TEL-empowered STEAM subjects, minding the value the arts acquire in the teaching and learning practices.

Each phase of this research will contribute to the development of these design principles. First, the analysis stage will help to elaborate on what digital practices of STEAM have functioned effectively, and in what ways those aspects can be integrated into a design together. Then, the key principles of multidisciplinary integrations are understood better and are merged in the initial development. Although certain practices and activities might have worked in the future, it does not ensure a functioning design when they are put together. The development and prototyping phase will help explore which combinations of design principles work well together, in the sense of engaging students by integrating two or more disciplines. The practical aspect of this research will demonstrate the methods of incorporating and utilizing the core design principles for multidisciplinary education in classrooms and distance education.

2.3. Timeline

This research will be undertaken in the nominal period of a doctoral degree in Estonia which is 4 years. To cover all aspects that are considered necessary in this research plan, each year of the doctoral study will have an overall theme of research. Although Figure 2 illustrates the timeline as a linear and progressive chart, the development phase consists of multiple cyclical studies that aims to clarify and advance the set of design principles to utilize in integrating numerous topics into an interdisciplinary learning context and outcome.

The first year focuses on analysis of the current knowledge and practices of STEAM in Estonian upper secondary schools (excluding vocational schools), and the exploration of the common attributes of digital tools of an effective and sustainable integration of arts into STEAM education. The second and third years will focus on development cycles that involve designing an intervention based on the design principles, testing it with teachers and students, and revising the design according to the feedback received from the users and the evaluation of whether the intervention enables other interdisciplinary work.

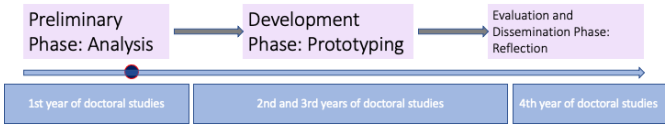

Figure 2: The brief timeline of this research

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