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Enhancing student engagement through instructional STEAM learning activities and self-explanation effect

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Abstract
The self-explanation effect (SEE) has great potential in strengthening student learning outcomes. With adequate instructional guidance, this potential is even higher. Our study aimed to examine to what extent direct instruction (DI) and indirect instruction (II) in science, technology, engineering, arts, and mathematics (STEAM) education can strengthen different types of student engagement, as well as whether and to what extent the SEE can support instructional STEAM learning and enhance student engagement. The research was conducted through a quasi-experimental design. The data were collected using an instrument–the engagement scale and were analyzed using confirmatory factor analysis (CFA), one-way ANOVA analysis, and paired sample t-test. The study involved 103 students aged 9-10 years. The results of CFA showed that the adapted version of the instrument for measuring four types of student engagement–emotional, behavioral, cognitive, and agentic–represents a valid and reliable measure for these purposes in primary education. In addition the results of one-way ANOVA analysis and t-test revealed that the usage of DI and II proved to be successful in enhancing all four types of student engagement in the performance of STEAM activities, whereby the combination of the usage of DI with the SEE was singled out as the most successful strategy. As a significant practical implication, this research underlines the need to create appropriate conditions for introducing the SEE in the teaching of STEAM.

Keywords: student engagement, direct and indirect instructions, self-explanation effect, STEAM learning

INTRODUCTION

The science, technology, engineering, arts, and mathematics (STEAM) approach has the potential to strengthen student engagement (Barlow & Brown, 2020; Chen & Huang, 2020; Maričić & Lavicza, 2024; Techakosit & Nilsook, 2018). This potential tends to grow if it is enhanced by adequate instructional guidance (Falloon, 2019; Gorjanac Ranitović et al., 2022; Herro et al., 2018; Maričić et al., 2023a, 2024). However, despite its popularity, there is limited research data on successfully leading STEAM learning, the contributions of different instructional approaches, and enhancing instructional STEAM learning to promote student engagement (Herro et al., 2018; Maričić & Lavicza, 2024; Silva-Hormazábal & Alsina, 2023). Several observations

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Contribution to the literature

- Considering that little is known about how to guide STEAM learning successfully, this research contributes to the literature by examining the contribution of different instructional support to promote student engagement during its implementation, as well as the potential of self-explanation effect (SEE) in enhancing the instructional STEAM activities.
- This study strived to fill the research gap about introducing the SEE into STEAM environment and examining its potential in strengthening direct and indirect STEAM guidance in the direction of enhancing student engagement.
- Considering the great practical potential of SEE in strengthening instructional STEAM learning and different types of student engagement, our study underlines the need for educators/practitioners to create appropriate conditions for encouraging the SEE in the teaching of STEAM.

have been made from these studies: professional development of teachers fosters positive perceptions of instructional STEAM learning; applying instructional guidance poses numerous challenges; teachers struggle with transitioning from direct to indirect guidance in STEAM learning; and indirect instruction (II) contributes somewhat more to student engagement than direct instruction (DI) (Darling-Hammond et al., 2017; Fulton & Britton, 2011; Herro et al., 2018; Maričić & Lavicza, 2024; Nadelson et al., 2013; Silva-Hormazábal & Alsina, 2023). All these elements are closely related and reflect the level of student engagement in classes. In addition to the above, the findings of these limited studies provide insights into the fact that optimal instructional guidance is crucial for the successful implementation of STEAM activities. Their contribution can be enhanced through the introduction of approaches that can support and deepen students' understanding of the learning process and content. One such approach is the SEE (Chi, 2000; Chi et al., 1994; Maričić et al., 2022a; Sidney et al., 2015), which encourages students to explain to themselves the content they have learned by summarizing the learning process, which can engage them at all levels (Sidney et al., 2015). The importance of SEE in education is primarily reflected in the promotion of different types of student engagement through the activation of germane cognitive load, which motivates and moves students into a deeper processing of teaching material (Kalyuga, 2011; Maričić et al., 2022a). These activities aim to reduce the extraneous load caused by the instructional design and primarily encourage students on a cognitive, behavioral, and agentic level, which results in greater satisfaction, i.e., strengthens the emotional type of engagement (Kalyuga, 2011; Maričić et al., 2022a; Reeve & Tseng, 2011; Sweller, 2010). Investing additional energy in the learning process–key information (the core of interaction elements) also strengthens student engagement, because engagement is defined as the level of invested/spent mental and physical energy in learning activities (Axelson & Flick, 2010; Christenson et al., 2012; Maričić & Lavicza, 2024; Sweller, 2010). The STEAM approach represents an interdisciplinary integration of different disciplines (Maričić & Lavicza, 2024; Perales & Arósteguib, 2021). The potentials of applying SEE within STEAM activities are also reflected in investing additional energy in various learning activities and eliminating the extraneous load (which in STEAM can be greater, i.e., caused by various factors) which can result in more productive learning, more versatile knowledge, and greater level of student engagement. However, within the STEAM learning environment, this issue has not been explored. To fill this research gap, we decided to conduct this research. For this purpose, we have chosen the emotional, behavioral, cognitive, and agentic engagement scale by Reeve and Tseng (2011), as well as students from primary school. Since the scale is designed for higher school students, it is necessary to verify its model fit to our sample. For these reasons, the aim of our research is threefold. Firstly, we aspired to determine whether the engagement scale can be validly and reliably used in work with primary school students. Secondly, we strived to examine the extent to which different instructions with STEAM activities can enhance different types of student engagement. Thirdly, we sought to investigate whether and to what extent the SEE can support instructional STEAM learning and improve student engagement.

THEORETICAL BACKGROUND

STEAM Approach and Student Engagement

The STEM approach emerged from society's general needs, industry demands, college and career readiness, and the need for a competent workforce. In contrast, the STEAM approach originated from the necessity to incorporate aesthetics, creativity, personal experience, expertise, and addressing authentic problems to create a better world to live in (Chen & Huang, 2020). Under STEAM concept we mean a trans-disciplinary approach in education that integrates at least two or more different disciplines from the acronym (Anđić et al., 2022, 2024b; Perignat & Katz-Buonincontro, 2018). The STEAM approach in the sphere of education is mainly implemented through STEAM school projects that integrate knowledge from science, technology, engineering, and mathematics, with the implementation of artistic experience, vision, design, and stylistics

(Anđić et al., 2022, 2024a, 2024c; Maričić et al., 2023b). This kind of integration offers many opportunities for students to be active, creative, involved, and to take initiative in their learning (Linder et al., 2016). The results of previous research on this topic provided insights that student participation in STEAM school projects develops not only different types of student engagement, innovative skills (creativity, critical thinking, problem-solving, collaboration, communication, literacy skills, etc.), positive perceptions towards this approach, but also student learning achievements/outcomes at a general level (Bassachs et al., 2020; Hadinugrahaningsih et al., 2017; Maričić & Lavicza, 2024; Maričić et al., 2023a; Ramma et al., 2018). In the meta-analysis by Perignat and Katz-Buonincontro (2018), which analyzed 44 studies on the topic of identifying the main intention of the STEAM approach, student engagement was singled out as one of the main ones. This construct greatly influences all other teaching and learning outcomes.

Engagement can be defined as a multidimensional construct, which includes the investment of mental and physical energy in educational activities, based on certain connections and states of the individual (Axelson & Flick, 2010; Christenson et al., 2012). Bearing this in mind, we can also define it as a state of emotional, social, and intellectual readiness of an individual for learning, characterized by activity, curiosity, and the drive to learn more (Abla & Fraumeni, 2019). Various authors have identified different types of engagement. Fredricks et al. (2004) described three types: emotional, behavioral, and cognitive engagement, while authors Reeve and Tseng (2011) introduced a fourth type–agentic engagement. Emotional engagement involves the presence of feelings such as interest, enthusiasm, enjoyment, and the absence of boredom, anxiety, or anger in students. It can be defined as the affective or emotional response of students to the subject of study, teachers, peers, and school (Sinatra et al., 2015). Behavioral engagement includes respect for community norms and participation in various activities, task-oriented attention, effort expended, persistence, effort, concentration, asking questions, participating in a discussion, and lack of conduct problems. It can be defined as the student's active participation in learning and tasks (Fredricks et al., 2004; Sinatra et al., 2015). Cognitive engagement can be defined as a process of interaction with teaching material, which is based on certain cognitive processes and involves the investment of cognitive effort (Chi et al., 2018; Sinatra et al., 2015). It includes thoughtfulness and readiness to put in the effort needed to understand complex ideas and master difficult ones (Sinatra et al., 2015). Agentic engagement involves intentional and proactive attempts by students to personalize and enrich their learning content, as well as the conditions and circumstances in which learning occurs. It can be defined as students' constructive contribution during the learning process, where students contribute, express preferences, and find interesting things to work on (Reeve & Tseng, 2011).

Instructive Guidance and Self-explanation Effect

Adequate instructional guidance plays a key role in the success of implementing the STEAM approach and promoting student engagement. Instructive guidance in teaching means the act of providing instructional support to students in acquiring or constructing knowledge, i.e., the provision of specific steps by the teacher to achieve the set outcomes (Anđić et al., 2024a; Cooper et al., 2010; Stronge, 2018). In teaching, two basic types of instruction are mainly used, alternated, and combined: DI and II. DI is defined as high guidance, organized around key concepts that the teacher provides to students step by step, providing them with all the necessary explanations, independent practice, feedback, and checking what they have learned (Maričić et al., 2022b). II is defined as minimal guidance, which is organized around key concepts, which are provided to students step by step in the form of activities or tasks that they should complete or solve independently (Anđić et al., 2024a). When applying II, students are not completely independent, but are offered IIs, which are embedded in the activities and tasks they need to perform (Bell et al., 2011; Lazonder & Egberink, 2013; Maričić et al., 2022b). Many studies have shown that instructional guidance can support learning (Alfieri et al., 2011; Clements & Joswick, 2018; Maričić et al., 2022a, 2022b). This process is even more successful if the instructions are empowered by an approach that, along with summarizing the teaching process, allows students a deeper understanding and repetition of what they learned in class. One such approach in education is the SEE.

Self-explanation represents an approach that places students in a position of self-explanation - mentally repeating what they have learned, connecting it with previous knowledge, thus restructure and shape it in a meaningful way (Chi, 2000; Chi et al., 1994). SEE involves students' attempts to understand new information by relating it to what they already know and making inferences to fill in the missing information (Chi, 2000). This approach can be a powerful learning strategy, and students can use it when learning by explaining new material to themselves or to other students. Even when learning materials are incomplete, with imperfect sequencing and significant information gaps, students can still learn effectively, and perhaps even more so, by attempting to explain the material to themselves. This process enables them to deduce the missing information, integrate the presented material even if it's not in the correct order, and so forth (Chi, 2017; Chi et al., 1994, 2018). Based on a meta-analysis by the authors Bisra et al. (2018), in which 64 research reports on the topic of explanations alone were reviewed, it was found that self-explanation prompts are a potentially powerful intervention across a range of instructional conditions. The authors conclude that the most powerful usage of self-explanation may arise after learners have made an initial explanation and then are prompted to revise it when new information highlights gaps or errors. Additionally, they conclude that another significant implication for teaching and learning is that the beneficial effects of inducing self-explanation seem to be available across most subject areas studied in school, encompassing both conceptual and procedural knowledge. Explaining concepts while learning results in deeper processing, powerful problem-solving, robust conceptual understanding, and better monitoring of teaching process (Chiu & Chi, 2014). If both DI and DI are strengthened by SEE, then students achieve significantly higher learning outcomes (Maričić et al., 2022a). Rittle-Johnson (2006) suggests that SEE can lead to lasting improvements in transfer success, regardless of whether it's combined with DI or invention. Both SEE and DI helped students learn and remember correct procedures, but neither method significantly improved conceptual knowledge on an independent measure.

SEE activities primarily aim to reduce extraneous load caused by instructional design and trigger germane cognitive load, a desirable - motivational type of load that has the potential to foster different levels of student engagement (Kalyuga, 2011; Maričić et al., 2022a; Reeve & Tseng, 2011; Sweller, 2010). By investing additional energy in the core of interaction elements, i.e., key information–concepts, student engagement is also enhanced, because engagement is defined as the level of invested/spent mental and physical energy in learning activities (Axelson & Flick, 2010; Christenson et al., 2012; Maričić et al., 2024; Sweller, 2010). This is exactly what reflects the potential of SEE application in STEAM education. By investing additional energy in various learning activities, through initiating the desired type of load and eliminating extraneous load, which in STEAM activities can be caused by numerous factors, students potentially participate in more productive learning, acquire more versatile knowledge, and are highly engaged at different levels.

Present Study

Research papers on the contribution of instructional STEAM learning are limited. Despite its popularity, little insight exists on how to successfully implement STEAM activities; how different types of instruction during STEAM activities contribute to learning outcomes; and even less about how the potential of instructional STEAM learning can be strengthened from the aspect of promoting student engagement (Herro et al., 2018; Janković et al., 2023; Maričić & Lavicza, 2024; Silva-Hormazábal & Alsina, 2023). In the limited amount of research on this topic, the following observations have been made:

- the professional development of teachers contributes to the development of positive perceptions about instruction in STEAM learning–which improves their practice and student engagement,
- the usage of different instructions carries numerous challenges (such as issues related to pacing, time, planning, student understanding of content and process, and concerns about school district policies), which is also reflected in the realization of STEAM learning and student activities,
- teachers find difficulties in the transition from direct to indirect guidance within STEAM learning, which leaves students in a more passive position, and
- II contributes to the development of different types of student engagement (emotional, behavioral, cognitive, and agentic) to a slightly greater extent than DI (Darling-Hammond et al., 2017; Fulton & Britton, 2011; Herro et al., 2018; Maričić & Lavicza, 2024; Nadelson et al., 2013; Silva-Hormazábal & Alsina, 2023).

These studies reveal that adequate instructional guidance is critical to the successful implementation of STEAM activities. Their potential can be strengthened through the introduction of approaches that can support and deepen students' understanding of the learning process and content. The literature suggests that this can be achieved through the SEE (Chi, 2000; Chi et al., 1994; Maričić et al., 2022a; Sidney et al., 2015). After receiving a certain type of instruction, students are encouraged to explain to themselves the content they have learned through summarizing the learning process, which can engage them at all levels (Sidney et al., 2015). Within the STEAM learning environment, this issue has not yet been explored. In order to contribute to the clarification of the role, contribution of instructional guidance, and the potential of its empowerment within STEAM activities i.e., to fill the mentioned research gap, we decided to conduct this study. For these purposes, we selected the 4-construct engagement scale by Reeve and Tseng (2011), as well as students from primary school (9-10 years old). Given that the scale is intended for high school students, it is necessary to check its model fit to our research sample. With the above in mind, the goal of our study is threefold.

- Firstly, we aspired to determine whether the engagement scale can be validly and reliably used in work with primary school students.
- Secondly, we strived to examine the extent to which different instructions with STEAM activities can enhance different types of student engagement.
- Thirdly, we ought to investigate whether and to what extent the SEE can support instructional STEAM earning and improve student engagement.

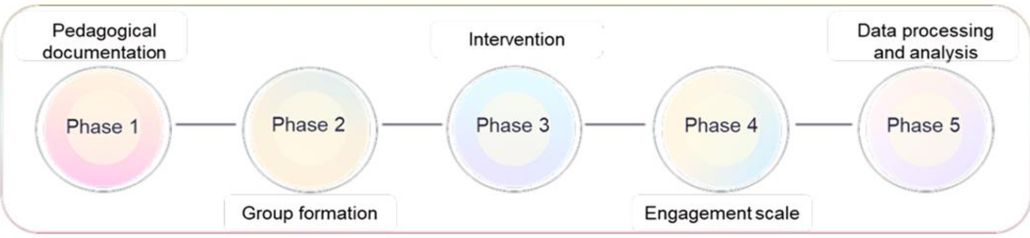

Figure 1. Phases of research (Source: Authors' own elaboration)

METHODOLOGY

Research Design

The research is quasi-experimental and was conducted according to the design of the experiment with parallel groups, through the following phases (**Figure 1**).

Pedagogical documentation

For the purposes of this research, schools from one region in Eastern Europe were recruited. Within these schools, classes of third-grade students were selected. Then we began to collect pedagogical documentation, i.e., their average grades in the subject of natural science (NS), as well as the average grades at the end of the completed previous i.e., second grade (SG). NS is a subject in which children of this age learn about natural phenomena and processes from the aspects of physics, chemistry, biology, and ecology. The average grade in the subject of NS represents the mean value of student outcomes achieved in this subject at the end of the first semester or school year. The average grade at the end of the SG represents the mean value of student outcomes achieved in all subjects at the end of the first semester or school year. Collected average grades were subjected to ANOVA analysis. Those classes of students that showed approximate average grades (I class: NS - M = 4.160, SG - M = 4.440; II class: NS - M = 4.423, SG - M = 4.577; III class: NS - M = 4.231, SG - M = 4.385; IV class: NS - M = 4.308; SG - M = 4.615) without significant difference between them (NS - F [3, 102] = .997, p = .446; SG - NS - F [3, 102] = .755, p = .522) were retained in the research.

Group formation

Retained classes represent previously formed classes (groups) of students, which is the basic feature of a quasi-experiment. The classes were randomly assigned to one of the following STEAM conditions: II group; DI group; II + SEE - II + SEE group; and DI + SEE group.

Intervention

After the creation of the groups, intervention was implemented. For this research, NS contents about electric current were selected, which was primarily implemented through hands-on experiments. These contents are integrated with technology, engineering, art, and mathematics through various activities. Technology is integrated through scientific simulations: *circuit construction kit: AC - virtual lab* from the PhET collection, which help present this content through a different modality and thus reinforce the understanding of basic scientific concepts about electricity. Art is integrated through the introduction of the landscape concept. In addition to this concept, elements of visual art were also introduced, such as observing original paintings by famous artists, painting one's own examples of landscapes, creating an original piece of art, which also showed an understanding of scientific concepts about electricity. Math is integrated through determining the dimensions of the original piece of art and its production according to the given measurements. Engineering is integrated through a practical activity i.e., through the creation of an original piece of art, which includes integrated knowledge from all the mentioned disciplines. The lesson was carried out through the following stages (**Figure 2**):

- *Artful thinking routine*–in the introductory part of the intervention, the students observed the painting by the famous painter Leonid Afremov– *under the lights* and through a conversation with the researcher about the painting, they came to the concept of light–streetlights, through which the term circuit was introduced.
- *Science review*–through real and simulation hands-on activities, students learned the following concepts about electricity: electric circuit, source of electricity, conductor, consumer, switch, materials as conductors and insulators. As part of the simulation hands-on activity, the students performed two simulations in the virtual laboratory; circuit construction and testing of conductors and insulators. In the framework of real hands-on activities, students made different variants of the circuit, such as: an ordinary circuit on the table (using a battery, wires, a light bulb, a switch), a circuit on paper (using a battery, aluminum strips, LEDs), a circuit obtained using steel wool (using steel wool and a 4.5 or 9V battery), a circuit obtained with a solution (sodium chloride solution–NaCl).
- *Art session*–after adopting scientific concepts about the content of electric current, the concept of landscape was discussed with the students. They were shown different landscapes by famous artists,

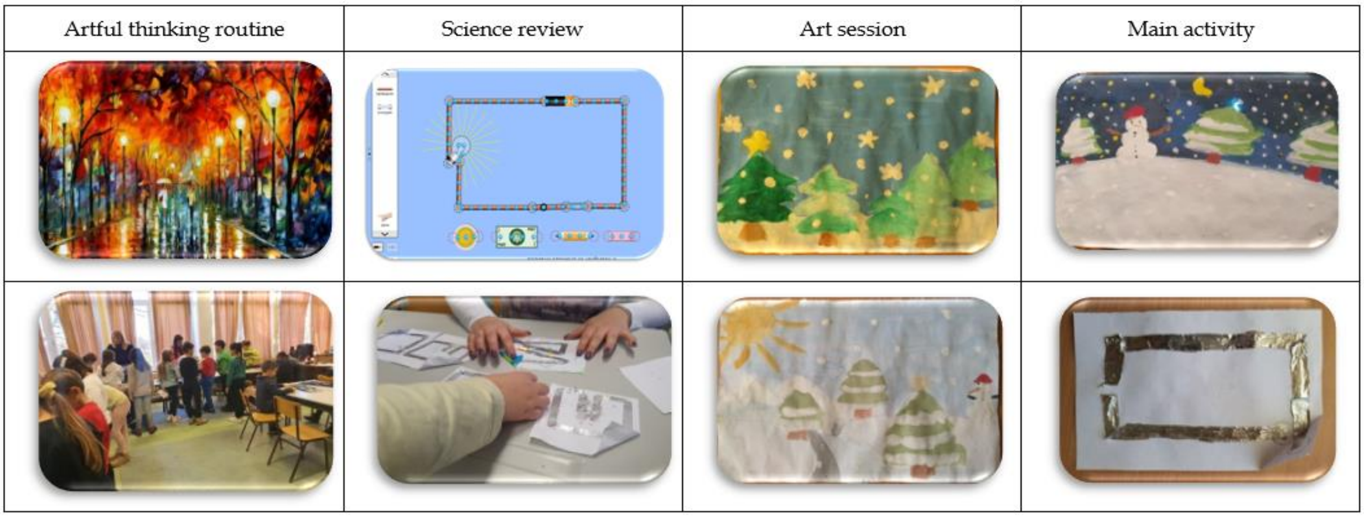

Figure 2. Phases of the lesson (Source: Authors' own elaboration)

such as Leonid Afremov and Van Gogh, where light sources are clearly visible. The students' task was to create their own landscape with the use of different art materials and media, on which they would clearly show a certain light source.

o *Creating original peace of art through main activity*– within this activity, the students' task was to create an original two-dimensional work of art that integrates elements of science, technology, art, and mathematics, through an engineering activity. The students chose to create a two-dimensional interactive New Year's card, which contained all the elements of a circuit. The card was created according to certain dimensions of the students, and it was made in accordance with them through an engineering activity, considering the knowledge from all the previously mentioned disciplines.

Work within II and II + SEE groups

The students of II and II + SEE groups learned the contents about electricity, as well as performed all the planned activities, with the follow-up of II, which was included in the instruction sheet. Following these instructions, they independently carried out hands-on experiments, activities within simulations, as well as activities for creating their own landscapes. The instruction was created in such a way that it clearly describes to the students all the steps necessary for the implementation to reach the correct solutions/results. Based on the obtained results, they independently answered the questions on the instruction sheet. The difference between these two groups was reflected in the usage of SEE. The students of the II + SEE group had the task of explaining the contents independently to themselves after having covered the content about electric current, while the students of the II group completed this task with the help of the researcher.

Work within DI and DI + SEE groups

The students of DI and DI + SEE groups went through the contents about electricity, as well as all the planned activities, following the researcher's DI and explanations. The researcher showed them the equipment and material necessary for the experiments, explained the procedure for performing the experiments, performed the experiments, as well as activities in the framework of simulations and landscape creation. The students' task was to independently repeat the procedure according to the researcher's principle, but also to give answers to the questions based on his explanations and observations. After performing all the experiments and simulation activities, the students of the DI + SEE group were placed in a position to explain to themselves the contents they were learning, while the students of the DI group completed this task with the help of the researcher.

The non-SEE and SEE groups

The basic difference between non-SEE and SEE groups is reflected in the way of explaining the contents–creating a self-explanation of learned concepts. The students of non-SEE groups repeated each learned concept (light, electric circuit, source of electricity, conductor, consumer, switch, materials as conductors and insulators, and landscape) with the help of the researcher, who once again explained their meaning in detail. The students then described (wrote) each concept in the place provided for it. Contrary to them, the students of the SEE groups were engaged so that they independently explained all the learned concepts to themselves in their own words. After mental processing, they wrote down each explanation in the place provided for it. The main difference in the work of students of the non-SEE and the SEE groups is provided in **Table 1**.

The final part of the intervention–the creation of an original piece of art with the integration of knowledge

Table 1. The difference in the work of students of the non-SEE and SEE groups

Non-SEE groups	SEE groups
Performing real hands-on experiments	Performing real hands-on experiments
Performing virtual simulations	Performing virtual simulations
Creation of landscapes	Creation of landscapes
Extracting results/solutions	Extracting results/solutions
Answering the questions independently	Answering the questions independently
Explaining the concepts by researcher	Explaining the concepts by themselves
Creation of original piece of art	Creation of original piece of art

from all the mentioned disciplines, was performed by the students of all groups independently to show their originality and express creativity to the greatest extent possible. During that time, the researcher supervised and assisted them as needed, but only in clarifying the task.

Engagement scale

After the end of the intervention, the students were given an engagement scale to determine the level of their perceived engagement. This questionnaire was given to the students immediately after the end of the lesson, in order to present their most recent perceptions about the different types of engagement whose development was encouraged through the STEAM activity;

Data processing and analysis

Immediately after collecting the data, we began to arrange and process it. For these purposes, in addition to descriptive statistics, various techniques from the SPSS program were also applied.

Sampling

For the purposes of this research, the convenience sampling method was applied, that is, schools (as well as students) were recruited from the environment that was available to the researchers. The recruited schools have a diverse body of students, i.e., they are attended by children from national minorities, as well as children who study according to the IEP. From these schools, third-grade students, who had approximately average grades in NS and at the end of the previous grade, were selected. Through this selection, children from four classes (1. N = 25 students, 2. N = 26 students, 3. N = 26 students and 4. N = 26 students) were kept in the research, i.e., a total of N = 103 students, aged 9 - 10 years.

In addition to the above, one of the basic conditions for the inclusion of students in the implementation of the research was their voluntary consent, the consent of their parents, teachers, and the school principal.

Data Collection

For the purposes of this research, the engagement scale by Reeve and Tseng (2011) was used. The original scale consists of four blocks, of which the emotional block was developed by Wellborn (1991), the behavioral block by Miserandino (1996), the cognitive block by Wolters (2004) and the agentic block by Reeve and Tseng (2011). Reeve and Tseng (2011) combined these blocks and added their own related to agentic engagement. In this way, they created an original scale for assessing student engagement. Before the realization of the research, permission was requested from these authors to adapt and modify the scale for our study, because the original version of this scale is intended to measure the perceptions of students from high school. For this reason, revisions were made in the scale items by taking expert opinion first. The modified version of the scale was given for verification by experts in the field, teachers with longer work experience, as well as the students themselves. This check resulted in several rounds of revision, which included grammatical and linguistic adaptation of the questions to students of that age. After confirmation by two experts in the field of methodology, five teachers with work experience of over 10 years, as well as five students aged 9-10 years, it was estimated that the scale meets the basis of validity and that it can be used within this research. The validity of the scale was also checked statistically using confirmatory factor analysis (CFA). Researchers with theory often find CFA more useful than exploratory factor analysis because the theory can be tested directly by analysis and different methods can optimize the empirical model's degree of fit (Avşar, 2007). The reliability of the scale was confirmed using the Cronbach's alpha coefficient. The values for CFA and Cronbach's alpha are given in the results section. The revised scale was adapted to 103 primary school students.

The adapted and modified scale consists of four main blocks: emotional, behavioral, cognitive, and agentic. Each block contains five closed type questions. With these questions, certain values in students were monitored within each block. Through the emotional block we observed the following values: enjoyment, fun, interest and curiosity. Within the behavioral block, we observed these values: careful listening, paying attention, and trying hard. Through the cognitive block, we observed the following values: reference to previous knowledge, reference to personal experience, connecting different ideas into a meaningful whole, creating our examples, and reviewing what was learned. Through the agentic block, we observed these values: the development of the following values: asking questions,

Table 2. Results of ANOVA analysis for students' engagement by instruction types

Type of engagement		Sum of squares	df	Mean square	*F*	*p*
Emotional	Between groups	1.213	3	.404	1.712	.169
	Within groups	23.376	99	.236		
	Total	24.589	102			
Behavioral	Between groups	.778	3	.259	1.636	.186
	Within groups	15.702	99	.159		
	Total	16.480	102			
Cognitive	Between groups	.385	3	.128	1.439	.236
	Within groups	8.832	99	.089		
	Total	9.217	102			
Agentic	Between groups	.960	3	.320	2.658	.052
	Within groups	11.914	99	.120		
	Total	12.874	102			

informing the researcher about personal interests, informing the researcher about the need to improve achievement, and suggesting ideas for teaching/learning improvement. Student engagement was assessed using a five-point Likert-type scale ranging from 1. I completely disagree with 5. I completely agree.

Data Analysis

Since the data showed normal distribution, parametric tests were used in the analysis of the data. A one-way ANOVA test was used to determine whether there was a difference in the students' engagement between interventions according to the instruction types, while a paired samples t-test was used to determine whether there were significant differences between different types of engagement, but within each group.

RESULTS

The skewness and kurtosis coefficients were calculated to examine the normality assumptions. In the literature; ±3 for skewness and ±10 for kurtosis are used (Kline, 2005). The skewness values of the data set vary between -1.147 and 0.707, and the kurtosis values vary between -1.166 and 2.636. Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity were used to determine the suitability of the data for CFA. Accordingly, the KMO value (0.866) and Bartlett's test of sphericity (1222.704) values were found to be statistically significant ($p < .000$). It was ensured that the sample size was sufficient for data analysis (Tabachnick & Fidell, 2007). The obtained values were accepted as an indication that CFA could be performed.

LISREL statistical analysis program was used for CFA in this study. We used various fit indices, primarily used to evaluate the model's fit to the data in CFA. As a result of the analysis carried out on 20 items, the RMSEA value was found to be 0.081. The values obtained at the end of the analysis (χ^2 [159, N = 103] = 264.4, $p < 0.00$, RMSEA = 0.081, SRMR = 0.082, NFI = 0.90, TLI = 0.95, CFI = 0.96). When examined, the fit criteria were calculated within acceptable ranges. In addition, the Chi-square/SD ratio was calculated to be less than 3 (1.66) (Schermelleh-Engel et al., 2003). For the reliability of the scale, the Cronbach's alpha coefficient was calculated as α = .905 (factor scores, emotional α = .906, behavioral α = .854, cognitive α = .703, agentic α = .678).

Table 3. Mean values of students within each type of engagement based on instruction types

Group	Emotional	Behavioral	Cognitive	Agentic
II	4.296	4.120	4.072	3.704
DI	4.923	4.169	4.085	3.731
II + SEE	4.385	4.161	4.161	3.846
DI + SEE	4.585	4.346	4.223	3.808

Students' Engagements According to Instruction Types

A one-way ANOVA analysis was used to examine whether there is a significant difference between students' engagement in terms of instruction types. The results are shown in Table 2.

According to the results presented in Table 2 it can be observed that there is no significant difference in students' engagement in terms of instruction types. Also, Table 3 shows the mean values of students' engagement across four types–emotional, behavioral, cognitive, and agentic–based on different types of instruction.

Figure 3 is a radial bar chart illustrating the mean engagement levels across emotional, behavioral, cognitive, and agentic engagement for students under different instructional types. Each segment represents one type of engagement, and the numbers shown indicate the mean value within that category:

- Emotional engagement is represented by the innermost segment, showing varying mean values, with DI (4.923) having the highest score, followed by DI + SEE (4.585).
- Behavioral engagement follows, with scores highest in the DI + SEE (4.346) category.
- Cognitive engagement is represented in the next segment, where DI + SEE (4.223) and II + SEE (4.161) scored similarly.

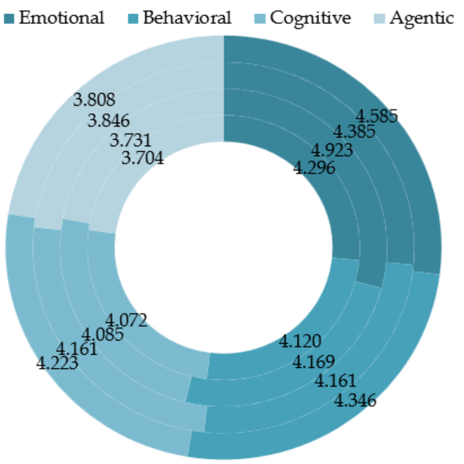

Figure 3. Mean values of students within each type of engagement based on instruction types (Source: Authors' own elaboration)

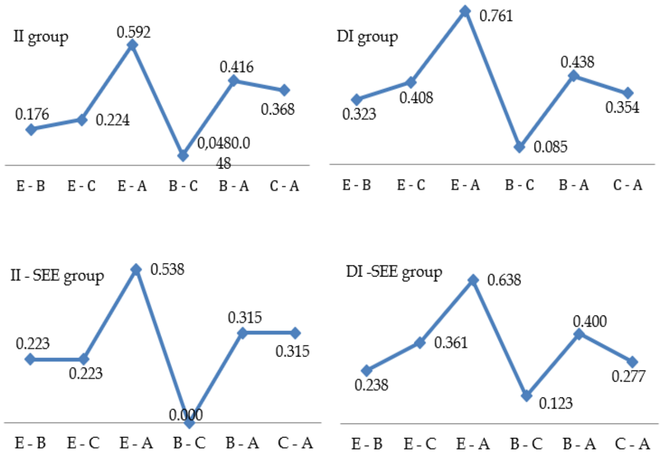

Figure 4. Differences in student engagement within each group (Source: Authors' own elaboration)

Table 4. Differences in student engagement within each group

Group		*M*	*SD*	*t*	df	*p*
II	E-B	.176	.437	2.013	24	.055
	E-C	.224	.452	2.477	24	.021*
	E-A	.592	.570	5.193	24	.000*
	B-C	.048	.279	.862	24	.397
	B-A	.416	.486	4.278	24	.000*
	C-A	.368	.394	4.665	24	.000*
DI	E-B	.323	.300	5.496	25	.000*
	E-C	.408	.433	4.805	25	.000*
	E-A	.761	.560	6.933	25	.000*
	B-C	.085	.248	1.742	25	.094
	B-A	.438	.411	5.428	25	.000*
	C-A	.354	.261	6.910	25	.000*
II + SEE	E-B	.223	.311	3.651	25	.001*
	E-C	.223	.405	2.807	25	.010*
	E-A	.538	.556	4.934	25	.000*
	B-C	.000	.226	.000	25	1.000
	B-A	.315	.424	3.793	25	.001*
	C-A	.315	.316	5.092	25	.000*
DI + SEE	E-B	.238	.247	4.929	25	.000*
	E-C	.361	.411	4.476	25	.000*
	E-A	.638	.490	6.644	25	.000*
	B-C	.123	.320	1.959	25	.061
	B-A	.400	.404	5.049	25	.000*
	C-A	.277	.340	4.156	25	.000*

- Agentic engagement is represented by the outermost segment, with the highest score for II + SEE (3.846), followed closely by DI + SEE (3.808).

Students' Engagements Within Each Group

Differences between different types of students' engagement within each group were examined using a paired-sample t-test. The results of this analysis are shown in **Table 4** and **Figure 4**. **Table 4** details the statistical analysis of the differences in student engagement within each instructional group, using t-tests to compare paired engagement types. The asterisks (*) next to the p-values indicate statistically significant results. These signify that the observed differences in engagement types within each group are significant at the conventional threshold ($p < 0.05$).

Figure 4 presents the differences in student engagement within each group based on four engagement types–emotional (E), behavioral (B), cognitive (C), and agentic (A). The graphs for each instructional group (II, DI, II + SEE, DI + SEE) show how engagement types vary when compared against each other (e.g., E-B, E-C, E-A, etc.). Each point on the line graph indicates the mean difference between the respective engagement types, with peaks and troughs representing higher and lower differences, respectively.

There is a significant difference between the different types of student engagement within each group. Within the II group, there is a significant difference between all types of engagement, except between emotional and behavioral (p = .055), as well as behavioral and cognitive (p = .397). Significant differences within the DI group were observed between all types of engagement except between behavioral and cognitive engagement (p = .094). Within the II + SEE group, a significant difference was observed between all types of engagement, except between behavioral and cognitive (p = 1.000). Significant differences within the DI + SEE group were observed between all types of engagement except between behavioral and cognitive engagement (p = .061). The data indicate that across all types of instruction (II, DI, II + SEE, and DI + SEE), there is generally no significant difference between behavioral and cognitive engagement. This means that, regardless of the type of instruction used, the levels of behavioral and cognitive engagement among students are relatively similar and do not differ significantly. The data also indicate that emotional and agentic engagement show significant differences across the various types of instruction, suggesting that these engagement types are more sensitive to changes in instructional strategies compared to behavioral and cognitive engagement.

DISCUSSION

This research was aimed at testing the metric characteristics of the adaptation of the instrument for measuring student engagement (Reeve & Tseng, 2011) in the population of primary school students. On the other hand, an effort was made to examine to what extent DI and II with the implementation of appropriate STEAM activities can contribute to different types of student engagement. In addition, one of the directions of the research was to determine whether and to what degree the SEE can support the process of instructional STEAM learning and contribute to various aspects of student engagement.

Validation of the Engagement Scale

When it comes to the validation of the adapted instrument for examining the level of student engagement (Reeve & Tseng, 2011), in the sample of primary school students, the results of the CFA (Avşar, 2007) showed that, with appropriate adjustments, carried out in consultation with experts, it can be a reliable and valid measure of different levels of engagement, not only in the population of high school students but also in the younger age group, in students attending primary school. CFA confirmed its four-factor structure, which represents measures of four types of student engagement - emotional, behavioral, cognitive, and agentic. The reliability of the instrument as a whole, composed of 20 items, proved to be high, while the reliability of individual subscales composed of 5 items each, which measure four aspects of student engagement - emotional, behavioral, cognitive, and agentic, is also satisfactory. Those findings indicate that the adaptation of this instrument can be used with appropriate validity and reliability to measure four aspects of student engagement in primary school. The obtained results are by the initial expectations of the authors, derived based on the criteria within the definition of theoretical concepts of certain types of student engagement (Chi et al., 2018; Christenson et al., 2012; Fielding-Wells et al., 2017; Fredricks et al., 2004; Reeve & Tseng, 2011; Sinatra et al., 2015), as well as the results of previous validations an original instrument for measuring the level of different aspects of student engagement, conducted on a population of primary and high school students (Maričić & Lavicza, 2024; Reeve & Tseng, 2011). The special contribution of this validation of the instrument is reflected in the fact that it proved to be a relevant and reliable measure of all four aspects of student engagement at primary school age, in the domain of STEAM education (Barlow & Brown, 2020; Linder et al., 2016; Perignat & Katz-Buonincontro, 2018; Techakosit & Nilsook, 2018), which is gaining a great importance, especially in this age period.

Contribution of DI and II to Student Engagement

To some extent, the unexpected result indicates that there is no difference in the levels of student engagement depending on the type of instruction applied. Namely, considering the theoretical concepts of applying DI and II in the teaching process (Clements & Joswick, 2018; Cooper et al., 2010; Kirschner et al., 2006; Stockard et al., 2018; Stronge, 2018), as well as taking into account the results of previous studies, which refer to the degree of student engagement in the context of usage of certain types of instruction in teaching (Bell et al., 2011; Darling-Hammond et al., 2017; Fulton & Britton, 2011; Herro et al., 2018; Lazonder & Egberink, 2013; Maričić et al., 2022a; Moon & Brockway, 2019; Silva-Hormazábal & Alsina, 2023; Zhang, 2019), it would be expected that the II contributes to greater student engagement in the implementation of STEAM activities. The usage of II implies a more active, independent student, who is in the focus of learning, and from whom greater engagement is expected, where the teacher is less the one who gives concrete guidelines and solutions, and the student constructs knowledge more independently and comes to the relevant answers (Kirschner et al., 2006; Linder et al., 2016; Stockard et al., 2018). Based on that, it can be assumed that the usage of II will contribute to a higher degree of emotional, behavioral, cognitive, and agentic engagement of students when applying the STEAM approach or at least greater engagement in the domain of some of these four aspects of student engagement (Abla & Fraumeni, 2019; Axelson & Flick, 2010; Bassachs et al., 2020; Christenson et al., 2012; Fielding-Wells et al., 2017; Hadinugrahaningsih et al., 2017; Linder et al., 2016). However, it can be concluded that within the implementation of the content of STEAM education, regardless of whether DI or II are applied in teaching, the degree of emotional, behavioral, cognitive, and agentic engagement will be approximately equal. This means that whether it is a more or less guided approach to teaching, with a higher or lower level of guidance from the teacher, where the student will be more or less independent in constructing knowledge, understanding concepts and procedures, and drawing appropriate conclusions and applying the content, student engagement in terms of emotional, behavioral, cognitive and agentic engagement aspects should be equally. Therefore, regardless of the chosen type of instruction, students will be approximately interested in the content, motivated, and dedicated, will actively participate in the teaching process and respect the rules, effectively self-regulating learning, and contribute to enriching the content and circumstances in which they learn (Chi et al., 2018; Reeve & Tseng, 2011; Sinatra et al., 2015). It is possible that the type of teaching content itself, namely STEAM, which has been shown in previous research as an approach that contributes to the cognitive and affective components of engagement, contributed to the equal success of the usage of both DI and II, in terms of all four types of student engagement of primary and secondary school students. So students positively perceive activities within STEAM, as interesting, they direct their attention more effectively towards the problem, encourage them to actively participate, engage, and contribute to the experience of self-efficacy and success (Fielding-Wells et al, 2017). Other authors also concluded that the STEM curriculum provides students with opportunities for more intense engagement and the possibility to take the initiative in learning (Bassachs et al., 2020; Hadinugrahaningsih et al., 2017; Perignat & Katz-Buonincontro, 2018; Linder et al., 2016). Therefore, when the characteristics of the STEAM approach itself are considered, both DI and II may be equally successful in terms of encouraging student engagement, which allows teachers to use and combine them in an optimal way and somewhat more relaxed, without excessive fear that the individual activity and overall engagement of students will be neglected.

Contribution of DI and II Strengthened by SEE to Student Engagement

When it comes to examining the usage of an appropriate instructional approach and the SEE in the domain of student engagement, the findings of this research proved to be particularly interesting, indicating that the highest levels when it comes to all four types of engagement–emotional, behavioral, cognitive, and agentic, students achieve when DI is applied with SEE in STEAM environment. When considering the characteristics and effects of SEE, which involves intensive reflection on what is being learned and a deep understanding of the content, through making sense of new information, connecting with what is already known, and concluding what is missing, it becomes clear why it is a very effective learning strategy, helping students to identify gaps in their understanding of the content and supplement them with appropriate components from the instructional materials. At the same time, students can have their ideas about the topic and conceptual models, which with the help of SEE they better understand, revise and transform, and gradually harmonize them with the instructional materials (Chi, 2017; Chiu & Chi, 2014; Sidney et al., 2015). This finding has special importance for practitioners, who deal with the implementation of STEAM education because it unequivocally suggests that when processing STEAM content, in terms of encouraging emotional, behavioral, cognitive, and agentic engagement of students, the highest contribution will have the usage of DI with the encouragement of SEE. Therefore, when implementing the STEAM approach, students need to be given clear and precise instructions and guidelines, while at the same time, SEE will be encouraged, which contributes to better understanding and analyzing the contents, to the perception of their potential, limitations, and space for further advancement, and to additionally engage in the cognitive, affective, behavioral, and agentic domain, to be as efficient and successful as possible in achieving the expected learning outcomes (Bisra et al., 2018; Chiu & Chi, 2014; Falloon, 2019; Rittle-Johnson, 2006; Sidney et al., 2015).

CONCLUSIONS, CONTRIBUTIONS, LIMITATIONS, AND RECOMMENDATIONS

The results of our study provide both significant research and practical contributions. The adapted version of the instrument for measuring emotional, behavioral, cognitive, and agentic engagement has proven valid and reliable for use in primary education settings, extending its applicability beyond high school. Our study revealed that while DI and II are equally successful in fostering all four types of student engagement during STEAM activities, the combination of DI with the SEE stands out as the most effective strategy for enhancing student engagement. Notably, emotional and agentic engagement were shown to vary more significantly with instructional strategies compared to the relatively stable behavioral and cognitive engagement. This highlights the practical need to create conditions that support the SEE in teaching, particularly for STEAM education in primary schools, to maximize engagement across all dimensions. Limitations include the sample size and the focus on primary education, suggesting that future research should expand to include high school students and broaden the STEAM content scope to align with the STEAM + X concept.

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Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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