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About STEAM and Possibilities of Its Application in the Teaching Process from the Perspective of Fine and Visual Arts

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Abstract

This paper is a result of research which was presented for the first time at a meeting of the Visual Arts Teachers County Council in Zadar, on March 12, 2021, under the title STEAM and Fine and Visual Arts Education. At the time, the research was presented in its incomplete, unpublished form. Within the research, STEAM was examined as a teaching approach which incorporates STEM areas, arts and humanities. That is why emphasis is primarily placed on STEM and the context it originated from, and then on STEAM, which was an upgrade from STEM in the same education system in the USA. Specific features of STEAM are cooperation, transdisciplinarity and creative process. Possibilities of integration of STEAM into the teaching process are being analysed, as it fits cross-curricular topics which are promoted in various guidelines in the field of education in Croatia. With regard to that, the paper presents a research on the application of STEAM in the teaching process. The implementation of STEAM was based on "STEM and ART go hand in hand!", a workshop held at the 17th Science Festival organized with the students at the University of Zadar, in 2019. In that workshop, the areas of STEM, art and humanities were merged to create an interactive art installation Your uncertain shadow (colour), created using light (colour) and movement, by a famous artist Olafur Eliasson.

Key words: *additive colour mixing; method of aesthetic transfer; Olafur Eliasson; STEM; transdisciplinarity.*

Before STEAM

As STEAM was an upgrade from a more widely known concept of STEM, it would be appropriate to start with STEM. It is a coined word which was created as an

acronym for (natural) sciences, technology, engineering and mathematics. It was a more memorable term than the previously used SMET, coined in 2001 by Judith A. Ramaley, who was working for the National Science Foundation (NSF) at that time (Breiner, Harkness, Johnson, & Koehler, 2012).

STEM as an acronym was quickly accepted by the creators of curricula at national, state and local levels in the USA, as well as by the American scientific community. It was thought that the areas encompassed by STEM were important segments of the education reform based on the efforts invested in making them more competitive at the global level (Breiner, Harkness, Johnson, & Koehler, 2012). Sahin i Yildirim (2020) maintain that the importance of STEM areas was gradually recognized by other countries, among which they pointed out Turkey, and which, like the USA, had invested substantial means in their development within their respective education systems.

When we talk about STEM in its present form, it should be pointed out that its meaning has changed over time. Firstly, it was defined by the National Science Foundation as a broader concept into which it was planned to include, apart from natural sciences areas, some social sciences, such as psychology, economy, sociology and political sciences (Breiner et al., 2012 according to: Green, 2007). However, it is obvious that narrower perspectives of some other agencies were more powerful, as suggested by Kocabas, Ozfidan and Burlbaw (2020). In addition, it should be mentioned that an integrative approach to STEM areas in the teaching process was more clearly articulated only in more modern concepts (Breiner et al., 2012 according to: Labov, Reid, & Yamamoto, 2010; Sanders, 2009).

Sanders (2009) refers to this integration (*Integrative STEM Education*) as a direction which should have been taken. According to him, STEM is nothing more in its core than a simple abbreviation for four separate, different areas, and in the context of education, STEM (*STEM Education*) includes nothing more than teaching and learning of the same four areas in a conventional way, within separate school subjects. Contrary to this view, he sees an integrative approach to STEM areas applied in the teaching process in the learning and teaching of two or more intertwined STEM school subjects and/or intertwined school subjects from STEM areas with one or more different school subjects.

Sanders (2009) explains the importance of the integrative approach by noticing that just as technological advancements cannot be separated from the social and aesthetic context they belong to, neither can teaching and learning in STEM areas be separated from the learning and teaching in the social, artistic and humanistic areas.

Recently, similar tendencies have become more pronounced in various initiatives for joining the area of art (A) to the acronym in a broader approach called STEAM. According to Seletković (2017), the new acronym enriches the previous one, as art education makes a positive contribution to the development of self-confidence, skills and everyday problem-solving skills in students.

About STEAM

The name of John Maeda is often closely related to the term STEAM. Maeda is a versatile artist and graphic designer, with great interest in science and technology. From 2008 to 2013, he was a director of The Rhode Island School of Design (RISD), a famous higher education institution which he left to start a career in Silicon Valley.[1] During his career in the education system, together with his colleagues at The Rhode Island School of Design, he promoted the STEAM idea supporting it with the belief that STEM, on its own, would not lead to significant 21st century innovations unless intertwined with art. He further explained that art would help add the goal-oriented convergence of STEM a divergent approach typical of those who *wander* professionally (Maeda, 2013).

These and similar efforts described above, like the one made by Sanders (2009), contributed to the so-called STEM to STEAM movement, which was vivid in the USA in the previous decade. Ghanbari (2015) states that this movement was a reflection of some joint projects of American state agencies in charge of equal promotion of STEM and art.

As STEAM is an American term, closely linked to American education policy, it is precisely where its main definition should be found, as was the case with STEM. According to a report by *Education Commision of the States*, a US state agency, STEAM implies a teaching and learning approach which promotes critical thinking and creativity in problem solving at the point where natural sciences, technology, engineering, art and mathematics intersect (Dell'Erba, Education Commission of the States, A. E. P. (AEP), 2019). It should be noted that the letter A in the abbreviation often refers to the area of humanities, as mentioned by Herro, Quigley, Andrews and Delacruz (2017).

The above mentioned report states that the problems solved in that way stem from the interests and everyday environment of pupils and students, while its unique value is transdisciplinary thinking which is developed when analytical thinking (most frequently related to STEM) merges with creative expression (most frequently related to art) with the aim of creating innovation.

It is emphasised in the report that STEM implies the integration of various areas, but in a way that enables each area its independence, while final results achieved through this approach do not belong exclusively to any of the mentioned areas.

If this description is supported with research in practice, which is mentioned by Bertrand and Namukasa (2020), and Liao (2016), another important feature can be attributed to STEAM – the creative process, which becomes pronounced in this approach.

Still, it should be noted that linking STEM areas to analytical thinking development and art to creative thinking development, as mentioned by Maeda (2013), is a quite

[1] Rhode Island School of Design. *John Maeda Moves On.* (2014). https://www.risd.edu/news/stories/john-maeda-moves-on/

simplified understanding, as neither analytical nor creative thinking, including the creative process, belong exclusively only to one area.

Sousa and Pilecki (2018) explained the above mentioned division of analytical and creative thinking into areas by common conceptions about scientists, mathematicians and engineers as individuals interested in logic, analysis and precision. On the other hand, artists are viewed as creative individuals, interested in holistic approach and visualisation. These authors believe that misconceptions like these have additionally supported misinterpretations of research on the functions of the left and the right side of the brain, which go as far as dividing people into groups accordingly. However, the fact is that thinking, learning and behaviour of an individual do not become dominant due to the analytical left nor the visual right side of the brain. Both sides of the brain simultaneously process enormous quantities of data on a daily basis, and working together, they provide us with a complete insight into what is happening around us.

In addition, *creative* art should probably be observed as an attempt to establish its role in education. As stated by Zimmer (2019), art and humanities are less appreciated in the USA in comparison to STEM, which is more linked to the world of business and is therefore traditionally more supported.

If we take a look at contemporary economy, we can find new, attractive professions in which younger generations seem to be more and more interested, and which are also mentioned in a report by American Commission. These professions include animation, design, urban planning, health services (various kinds of therapy, biomedical engineering, dental medicine, plastic surgery, etc.), audio engineering, and video games development (Dell'Erba et al., 2019). That being said, it is obvious that nowadays art should not be promoted only because it has been neglected for a long time in comparison with other areas in education systems, but also because of its economic significance.

The economic significance of art can be found in creative industries which include architecture, design, video games, new media, etc., all of which are referred to by Jobst (2020) as the dominant area of interest in the 21st century. Jobst claims that creative industries in Croatia are still in the phase of formal organization, but that efforts are being made to recognize the importance of that sector.

A positive example of these efforts is a fast-growing video games development sector, towards which some high-school curricula in Sisak and Novska have been oriented.

STEAM, cooperation and transdisciplinarity

As STEAM is a relatively new concept in education, it has raised some questions. Some of them are related to difficulties associated with devising ways in which such an approach could be implemented in the teaching practice, and determining the professional profile of teachers who would be qualified to implement such teaching practice.

In their book, Sousa and Pilecki (2018) primarily address (American) STEM teachers by supporting their expectations to include art in their teaching process, but they point out that cooperation lies at the heart of STEAM. They believe cooperation should be included in the phase of planning the teaching process, as well as in the teaching and learning process, primarily when it comes to artistic areas, such as music and stage art, the performance of which depends on experts in various fields.

Herro et al. (2017) also believe that cooperation is a quality starting point. They describe it as one of the most important 21st century skills, suitable for development of transdisciplinary thinking, in which emphasis is placed on the holistic perspective of the problem and its solution by employing competencies in various fields. In line with that, they believe STEAM is a cooperative approach to problem solution, aided by the competencies in each of its fields and by project learning, creative use of technology and divergent approach.

They believe that the above described starting point that is found in the problem, not in the areas, is an important difference between the transdisciplinary and multidisciplinary approach, from the methodological perspective. Multidisciplinary approach is often based on themes (Herro et al., 2017 according to: Wickson et. al, 2006), an example of which are project days organized in Croatian education system.

Cerovac (2013) describes these differences in a similar way, including multidisciplinary and interdisciplinary approaches into disciplinary approaches. There are two reasons: they imply the joint work of experts in various fields, each holding on to their approaches and views (multidisciplinarity) or they work together at points where their respective areas intersect, so this can be understood as building a common model for the disciplines involved (interdisciplinarity).

On the other hand, Cerovac (2013, p. 20) describes transdisciplinarity as integrative research which requires a higher dimension of interactivity. In the process of research, experts in various fields make joint and comprehensive effort to solve the same problem, but in a way that would not diminish the importance of any respective area.

Mishra, Henriksen and *The Deep-Play Research Group* (2012) state that the main values of transdisciplinary thinking which enables such a creative transfer of information from one area to another are specific cognitive skills such as perception, sampling, abstraction, embodied thinking, shaping, play and synthesis, which can all be associated with both science and art.

Therefore, it is not surprising that the same authors relate their considerations on transdisciplinary thinking to an integrative approach to STEM in the teaching process, which is then transferred to STEAM as well. They point out that transdisciplinary thinking can take us much further, in terms of technology, which is their main interest.

It is clear that vast possibilities encourage enthusiasm, but they can create a sense of insecurity at the same time. This insecurity related to STEAM can be manifested in certain resistance. Zimmer (2019) states that some supporters of implementing STEM in the teaching process believe that insisting on introducing new areas in the

existing framework might interfere with the process of achieving the set outcomes. They also believe that, without an obligation of introducing A in the existing acronym, they introduced art in their teaching process whenever it was necessary to implement a STEM project.

Furthermore, some art pedagogues are critical of STEAM. They think that art does not belong to STEM and they stress its autonomy. In addition, there is quite a large number of those indifferent to STEAM, as they do not grasp its purpose (Zimmer, 2019).

The final argument is quite a strong one, especially when viewed against STEM, which is often seen as competitive. That is why the success of its integration in the teaching process in some countries, according to scientific research, is frequently associated with the PISA tests results. On the other hand, the main values of STEAM, such as a holistic view of a problem, cannot be measured in that way.

Finally, apart from the above mentioned resistance, attention should be paid to what at first seemed to be a positive initiative mentioned by Zimmer (2019), within which the role of art in STEM is seen as a means of attracting students into that area. Generally speaking, such an approach can be effective, but we should bear in mind that art is much more than simply warming students to some *more serious* areas.

STEAM from the Perspective of Education System in Croatia

Before considering the possibilities of STEAM in Croatian schools, it is necessary to refer briefly back to American schools, in which art has been integrated in the teaching process (*Arts Integration*) for a long time. According to Sousa and Pilecki (2018), STEAM can be viewed within the same timeline.

Such integration should be distinguished from the conventional school subjects in the field of art. According to the definition provided by The John F. Kennedy Centre for the Performing Arts in Washington (included in the integration story since 1976), it involves the learning and teaching approach in which students demonstrate their understanding of diverse content through artistic form of expression. In such a creative process, they detect connections between different types of content and achieve outcomes in various areas (Duma & Silverstein, 2014).

Sousa and Pilecki (2018) point out the significant contribution of two people who helped develop this approach. They are Howard Gardner and his multiple intelligences theory, and Maxine Greene, who invested enormous effort in introducing art into teaching.

In 2015, not so long ago, the integration described above was made relevant in the USA through a comprehensive *Every Student Succeeds Act* (ESSA). Its articles depict art as a basic constituent of a quality education process, where Dell'Erba (2020) finds another possibility for STEAM application.

Briefly, both STEM and STEAM, as well as Arts Integration, have stemmed from a specific educational milieu, which is different from the Croatian one and which is

not always easy to grasp. Regarding STEM, it should be noted that the launching of the Soviet Sputnik into the orbit in 1957 (Donnelly, 2019) is often mentioned as zero event in its history, revealing a lot about the motivation underlying it. Regarding STEAM and *Arts Integration*, it can be assumed that the initiatives which stem from art and which support art, have at least something to do with the fact that financing of public schools in the USA is not equal and, in moments of crisis, art is the area which is sacrificed first (Thompson, 1994; Gregory, 2017).

Insufficient number of art lessons in primary schools and in secondary schools whose curricula include art lessons, and uncertain status of art subjects, present a problem encountered by art teachers in Croatia. As far as this particular research is concerned, it should be noted that the above mentioned problem was an incentive for starting research on STEAM as a possibility to solve the current status of art (especially fine and visual arts) in schools, and to promote its value on the market. The propagandist starting point of the research which began from the affirmation of one area, was replaced by a different perspective throughout the research. It is in line with STEAM, in which, as has already been mentioned, problem solving is the most important aspect. It attaches more importance to the connections formed between various disciplines aimed at solving the problem than the importance of the individual disciplines themselves. At the same time, these connections are also important and present in the education system in Croatia, which means that there is an adequate legal framework for STEAM, as well as for any other integrative concept.

If attention is focused on fine and visual arts, then the school subject Visual Arts, taught in primary school in Croatia, also contains the desirable practice of cross-curricular connections in a form of structural, rather than thematic correlation. This correlation was emphasized in the *The syllabus for primary school in the Republic of Croatia* (NN, 102/2006), the former strategic document for the teaching process conducted in primary schools. The reason for emphasizing structural correlation is the common attitude in practice where art has an illustrative role while intertwining with other areas. According to Huzjak (2016), art is reduced to a motive being presented instead of pointing out the importance of its visual art content.

Unlike Visual Arts as a primary school subject, which stresses the visual form of students' expression, Art in secondary schools is based on systematic exploration of fine and visual arts, by which the emphasis is transferred from artistic to humanistic area. This transition, which coincides with the transition of students from primary to secondary school, has a double effect. On the one hand, it distances students from practical work, but on the other hand, it creates other opportunities for analysing the works of art in which attention is drawn to its contextual value. This was clearly pointed out in the *The syllabus for grammar schools* (Glasnik Ministarstva kulture i prosvjete, 1994), a document which contains concrete possibilities for cross-curricular correlation, not only with other school subjects in the areas of art and humanities, but also with STEM subjects, like Mathematics, Physics and Chemistry.

The document also mentions the importance of Physical Education, to which, from the modern perspective, we could also add Biology as a science subject and a wide range of social and technical sciences. However, what the document points out reveals a comprehensive framework of teaching and learning, which has existed in Croatian strategic documents for a long time.

New subject curricula in force since 2019 emphasize even further the cross-curricular connections, as well as the connection between school subjects and seven cross-curricular topics. As far as Visual Arts and Art are concerned, the cross-curricular component can be easily recognized in the titles of obligatory and optional topics to be worked on in the teaching process. It will suffice to mention only a few of them, such as *Nature and Shapes* and *Art and Community*. They are included in art in relation to other areas, as early as first grade of primary school (NN, 7/2019).

The workshop *STEM and ART go hand in hand!* as research on STEAM in practice

The workshop *STEM and ART go hand in hand!* lasted an hour and a half and was held on April 11, 2019 on the New Campus of the University of Zadar, for students attending the University at the time. There were 12 participants in the workshop – eleven fourth-year students of teacher studies from the Department of Teacher and Preschool Teacher Education of the University of Zadar (10 females and 1 male) and one student from another department of the same University. The workshop, designed and run by Assistant Professor Maja Cindrić, PhD, and the author of this article, was included in the 17th Science Festival programme. The topic was *Colours*.

The workshop was based on research of an interactive art installation by a famous artist, Olafur Eliasson, entitled *Your uncertain shadow (colour)* from 2010. Neither the artist nor the work of art were chosen randomly. Eliasson is an artist who regularly collaborates with a great number of experts in various areas, which had also been his practice before he created the above mentioned installation. In the introductory part of an interview from 2009, it is stated that Eliasson usually works with about thirty architects, archivists, artists and handymen in his Berlin studio. When asked why he worked with so many experts, he replied: "*I create works of art, but I need someone to look at them with me. I need others to make sure the world exists.*" (Peter & Eliasson, 2009, p. 34).

Apart from constantly collaborating with others, there is another thing that connects Eliasson with STEAM – his interest in natural phenomena. In the same interview, this can be seen in the dominant theme of light, which is not surprising, taking into consideration the fame he has received for the installation *The weather project* presented at Tate Modern in London in 2003. In addition to light, Eliasson announces movement as one of his interest in future work. Light and movement are precisely the main components of his installation *Your uncertain shadow (colour)*, whose documentation and formal description can be found on Eliasson's official website. To put it simply,

the installation is made of coloured lights lined on the floor parallel to a white wall. The empty space between is intended for the visitors who, when walking by, create ranges of colourful shadows on the wall.

The purpose and aims of the research and research questions

The aim of the research was to examine in practice the possibilities of STEAM in the teaching process by designing and implementing such activities that would, in a short time, present it to students as a potential integrative approach.

The aim of the research was to use Eliasson's installation and collaborate with the workshop participants to approach the additive colour mixing in an engaging way, and then use the connections with subtractive colour mixing as topics close to both science and art.

In line with the purpose and aims of the research, the following research questions were formed:

1 Does examination of Eliasson's installation from different perspectives, artistic and scientific, contribute to a complex impression and deeper understanding of this work of art?
2 Does examination of Eliassons' installation from different perspectives, artistic and scientific, contribute to a better understanding of the additive colour mixing as a natural phenomenon which can be explained from the scientific perspective, without examining a work of art?
3 Does the reconstruction of Eliasson's installation in the classroom environment contribute to a better understanding of the connections between the additive and subtractive colour mixing?
4 Does the creation of artwork based on Eliasson's installation, followed by a comparative analysis of this artwork and Eliasson's installation, contribute to understanding the difference between the additive and subtractive colour mixing and CMYK system and basic colours based on the Itten circle, which are usually the starting points in Visual Arts?

The mentioned four questions are linked to the concrete activities which were planned in the workshop. They stem from the most important research question listed below, which is evident in the purpose and aim of the research:

Can examination of Eliasson's installation, and the additive and subtractive colour mixing help detect strong connections between art and science?

Methodology

The research was designed as qualitative research, linked to the educational context, which influenced the choice of research methods.

Since the designed and implemented workshop was based on a work of art, the main research method was the method of aesthetic transfer, which is typical of fine

and visual arts education. The method implies a special approach to a work of art, the structure of which can be easily integrated in any Visual Arts lesson. According to Duh and Zupančić (2011), it consists of perception (perception of a work of art with all senses), reception (expression of pictures through words) and reaction (activity, a productive reaction to a work of art). The method of aesthetic transfer consists of three phases oriented to gaining a new aesthetic experience as the final value that can be achieved via this method.

Among the specific teaching methods used in natural sciences we should point out the experiment related to the reconstruction of a work of art in the classroom environment.

In addition to the above mentioned methods, some other methods, such as discussion and presentation, were used in the workshop. These methods are not typical of certain areas.

As far as students' artwork is concerned, as the material product of the research, each was examined analytically together with the workshop participants immediately upon its completion. It should be noted that some conclusions mentioned in the discussion on research results were drawn from the participants' interpretations.

Research plan

When the workshop was proposed for Science Festival, it was supposed to include the following steps, just as the research that followed:

1 examination of Eliasson's installation and Eliasson as an artist, in the ways typical of school subjects Visual Arts and Art;
2 reconstruction of his installation in the classroom environment in a form of an experiment typical of natural sciences;
3 analysis of the conducted experiment from the perspectives of physics and physical optics;
4 implementation of artistic tasks in group work (visual redefinitions of Eliasson's installation using collage as a technique);
5 reflection on the implemented activities and created artwork;
6 analysis of the research results.

Research implementation

Regarding the implementation of the research, it can be said that it followed the presented plan, with minor changes in the order of the phases. During its implementation, something that is also emphasized in STEAM became clear – artistic and scientific fields cannot be clearly divided. During the workshop, these two perspective were intertwined from the very beginning.

During the workshop, students were first shown photo documentation and then video footage of Eliasson's installation. They were encouraged to describe what they were looking at. When they realized it was a work of art which included light, colour,

shadows and visitors, they explored Eliasson as an artist, together with workshop leaders. They devoted special attention to his interest in natural phenomena which, as they concluded, were included in *Your uncertain shadow (colour).*

After that, students were briefly reminded of the nature of light and the way in which we see colours, as these are the topics they had covered in their primary and secondary education, within STEM subjects. In the following phase, they tried to reconstruct Eliasson's work of art in the classroom environment, using three pocket flashlights covered in red, green and blue (as the basic additive colours) transparent foils.

When they pointed their coloured lights at the wall, they firstly confirmed what they had known – the basic additive colours together create white light, and the mutual overlapping of each two of the mentioned colours creates the basic colours of the subtractive mixing. Walking between the source of light and the wall, by which colourful shades magically appeared on the wall, they became aware of the structural interdependence of the laws of nature and Eliasson's artistic vision.

Picture 1. Illustrations of the completed reconstruction of Eliasson's installation in the classroom environment (private album).

By comparing in a more focused way Eliasson's installation to their reconstructions, the students noticed that although the effect of both works of art was analogue, they were still different. The reason for that is that Eliasson did not use the three basic additive colours in his installation, but instead, he strategically distributed five lights on the floor: two green light next to each other, then magenta, orange and green light, which, together, resulted in the projection of white light on the wall.[2] In line with that, they concluded that the possibilities for manipulation and creative approach to the additive colour mixing are great, and they immediately associated it with stage art and other areas, such as film.

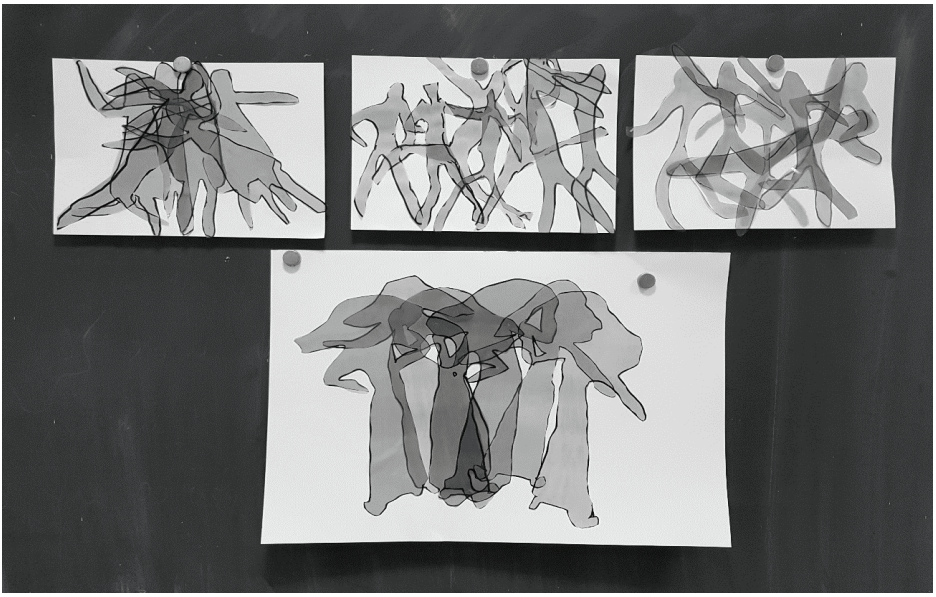
[2] Olafur Eliasson. *Your uncertain shadow (colour).* 2010. Retrieved on January 30, 2021 from: https://olafureliasson.net/archive/artwork/WEK100100/your-uncertain-shadow-colour#slideshow

In connection with their future teaching profession, students discussed how they would compare these conclusions about colour as light with the possibilities of colour mixing as pigment on paper. They were reminded of the basic subtractive colours on the wall that they had obtained by overlapping the basic additive colours, of the way in which printers work and of the role of CMYK cartridges in the process. They compared all these things with the basic colours of the Itten circle (red, yellow and blue), which are usually the starting point in Visual Arts, and concluded that various colours can be created in multiple ways.

The following phase included redefining Eliasson's work of art in collage as a painting technique, by gluing transparent red, yellow and blue foil on a white piece of paper. In the process, they did not forget that the cut out shapes should reflect multiplied shadows of human figures. For this purpose, they first made figures of wire and aluminium foil of similar proportions (which they created based on the basic proportion of human head and body height (1:/7)). In collaborative work that followed, they used the figures and pocket flashlights to draw the contours of the coloured shadows on foils. While drawing each new contour, they would move the figures a bit to create a sense of movement. In the end, they cut out the shapes and glued them on paper.

Picture 2. Students are creating their own redefinitions of Eliasson's installation in collage technique (private album).

The workshop ended with what it had begun: flat shapes of the coloured silhouettes, but with an important difference – in the end of the workshop, students were completely aware of what they had been looking at and of the transformation they witnessed in the process.



Picture 3. Students' artwork created during the workshop (private album).

Discussion on results

Although the presented students' artwork, which was the material product of the workshop, presented only partial results of the research, it is an important part of it as the research had not originally been planned as an ambitious one, followed by extensive documentation. Therefore, students' artwork, combined with the content of the section Research Implementation, provides answers to the listed research questions.

As the answer to the first question, relating to the usefulness of the research for experiencing and understanding a work of art, it can be said that the described approach contributed to its more complex experience and better understanding. However, it should be pointed out that the workshop managed to capture adequately only one aspect of the art installation, which is light. As far as movement is concerned, the time was too short to explain to the participants this particular feature of Eliasson's installation using the chosen methods. This can be seen in students' artwork which contains the necessary overlapping of colours, but the composition does not convey the rhythm and harmony of movement. We can assume that in order to achieve this goal, a longer time period would be needed to explore this aspect of the installation and to create artwork. In addition, it can also be assumed that cooperation with experts in the field of performing arts or kinesiology would be very useful.

The nature of the second research question, relating to the understanding of the additive colour mixing through exploration of a work of art, is not such as to make it easy to answer in a simple way. Still, based on surprise expressed by the workshop participants upon noticing the visual effects created in a simple experiment, and following a focused exploration of Eliasson's installation, it can be concluded that an approach of this kind is by all means encouraging in an educational context. We should nor disregard the fact that the experiment itself was not a motive for designing the workshop – the work of art was the motive. An important role of art is to draw our attention to something that is so familiar to us to that we do not notice it anymore. Eliasson is well aware of this role of art and he has been using it in his art, constantly reminding us that the connections between the visual and sensory qualities, explained in natural sciences and aesthetics, are strong.

Regarding the answers to the third and fourth question, relating to the contribution of the research to a better understanding of the connections and differences between the explored ways of colour mixing, it can be said that the research has achieved its goal. This is a relevant piece of data as it is important for the future teachers to notice various forms of colours. Within the first outcome of the *Creation and Productivity* domain in Visual Arts (LK A.1.1.) of the curriculum for first grade of primary school, the colours of the rainbow are listed, as well as primary and complementary colours (NN, 7/2019). This means that from the first day of schooling two aspects of colour are emphasized: colour as light and colour as pigment. This is something that should be kept in mind while implementing the teaching process.

Finally, the answer to the question if this kind of research can help notice a strong connection between art and science is affirmative. However, it should be pointed out that this research is only a minor illustration of that connection. The workshop had an illustrative purpose and was designed to introduce to students, the future teachers, STEAM as an integrative approach that they might use in their teaching. These circumstances and a short time frame for its implementation during the festival that aims to promote science among broader audiences were the reasons that the workshop was strongly guided, which can be seen in the presented artwork.

If the workshop had been run in stages, the workshop leaders would have participated in it as mentors. Greater emphasis would have been placed on the research approach, and the goal and outcomes would have been more complex. However, even in a short time frame, something very important was observed - the additive colour mixing, frequently explained in the teaching process through schemes in the textbook, can be transformed into a unique experience that can be a productive starting point of a creative process characteristic of STEAM in the teaching process.

Conclusion

STEAM, as a teaching approach which incorporates STEM areas and art and humanities, stems from the special features of the education system in the USA,

which should be kept in mind while exploring the possibilities of its implementation in another context.

Nevertheless, it is worth examining as, apart from the characteristics related to its source, STEAM contains numerous universal values. The paper places special emphasis on collaboration in problem solving, transdisciplinarity and the creative process. This kind of STEAM supports the best of the areas it incorporates, and it does not put these areas on the opposite sides. STEAM contains some of the ideas of the Renaissance man, who tends to take a holistic view of the challenges he faces. Generally, it is the greatest value of STEAM, and the one which is appreciated nowadays, taking into consideration the fact that professions in the creative industry are very attractive to younger generations.

The education system in Croatia welcomes STEAM, as well as any other integrative approach, especially viewed in the light of the valid subject curricula which rely on the cross-curricular correlations. It should also be pointed out that cross-curricular topics were also suggested in former strategic documents. Therefore, subject teachers and teachers in general should be encouraged to apply STEAM in their teaching process not only when they have an opportunity for that, but also in line with the outcomes set in the subject curricula and taking into consideration organizational aspects which are different in different schools.

This integrative approach, as well as other integrative approaches, should be motivating for classroom teachers, whose future colleagues participated in the workshop described in this paper and who experienced STEAM in practice. Correlation of diverse content helps them monitor students simultaneously in various fields of science and art.

STEAM can be very encouraging in this sense, as has been demonstrated in the paper, since it can bring together science and art in simple activities and at the same time bring them closer to us than when we perceive them as separate areas, detached from the context. Still, when choosing STEAM, there are several issues that should be taken into account.

First of all, this kind of integration should be carefully designed, each time choosing the topics, problems and examples which complement other types of content from science and art. Parallel to that, it would be useful to persist in establishing a productive cooperation with other experts in order to enrich different types of content and connect them in a more functional way. In addition, attention should be paid to selection of appropriate teaching methods, as STEAM is not a hermetic system. On the contrary, it relies on the process, meaning that it *lives* on the way in which it is designed and implemented and on its final results. Therefore, its value should not be assessed based only on the material products of an activity. In everyday teaching context, these results serve the purpose of reflection, leading to improvement.

Finally, STEAM should be viewed as an educational trend, as the paper points out, taking into consideration the way in which it was implemented. STEAM can really be understood as a trend, but it does not mean that it is superficial, and neither are other,

latest initiatives, like STREAM (STEAM + Reading). They can rather be perceived as enthusiastic attempts aiming at transferring the emphasis from disciplinary approaches to a functional role of certain disciplines while solving common problems. When this kind of thinking is applied in teaching, problem solving soon transforms into a creative process, which is not always straight, but which always makes the teaching process a unique experience.

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O STEAM-u i mogućnostima njegove primjene u nastavi iz perspektive likovnih i vizualnih umjetnosti

Sažetak

Rad je rezultat istraživanja koje je u svojem djelomičnom obliku, kao neobjavljeno izlaganje pod naslovom STEAM i vizualno-likovni odgoj i obrazovanje, prvi put bilo predstavljeno na Županijskom stručnom skupu za nastavnike likovne umjetnosti u Zadru 12. ožujka 2021. godine. Radom se istražuje STEAM kao odgojno-obrazovni pristup u nastavi koji uključuje područja STEM-a te umjetnost i humanističko područje. U tu se svrhu pažnja prvo usmjeruje na STEM i kontekst iz kojega je potekao, potom i na STEAM, nastao kao nadgradnja svojem prethodniku STEM-u u okviru istoga, odgojno-obrazovnoga sustava SAD-a. Kao osobitosti STEAM-a ističu se suradnja, transdiciplinarnost i kreativni proces te se razmatraju mogućnosti njegova provođenja u nastavi, osobito s obzirom na međupredmetno povezivanje koje uključuje, a koje se promiče i krovnim odgojno-obrazovnim dokumentima u Hrvatskoj. U skladu s time radom se prezentira jedno istraživanje vezano uz primjenu STEAM-a u nastavi. Njegova se provedba bazirala na radionici STEM i ART idu skupa! održanoj 2019. godine u okviru 17. Festivala znanosti realiziranoj u suradnji s tadašnjim studentima Sveučilišta u Zadru. Na provedenoj radionici se prožimanjem područja STEM-a te umjetnosti i humanističkoga područja pristupilo interaktivnoj instalaciji Your uncertain shadow (colour) poznatog umjetnika Olafura Eliassona, sazdanoj od svjetlosti (boje) i pokreta.

Ključne riječi: *aditivno miješanje boje; metoda estetskoga transfera; Olafur Eliasson; STEM, transdisciplinarnost.*

Prije STEAM-a

Kako je STEAM nastao kao nadgradnja svojem poznatijem prethodniku STEM-u, bilo bi primjereno s njime započeti. STEM je američka kovanica nastala kao akronim za (prirodne) znanosti, tehnologiju, inženjerstvo i matematiku. Nju je kao zvučniju inačicu od ranije poznatoga SMET-a 2001. godine osmislila Judith A. Ramaley, tada zaposlena u organizaciji *National Science Foundation* (NSF) (Breiner, Harkness, Johnson i Koehler, 2012).

STEM su kao kraticu brzo prigrlili kreatori odgojno-obrazovnih programa na nacionalnoj, državnoj i lokalnoj razini u SAD-u kao i tamošnja znanstvena zajednica smatrajući područja koja obuhvaća važnim segmentom odgojno-obrazovne reforme vezane uz nastojanja za povećanjem njihove konkurentnosti na globalnoj razini (Breiner et al., 2012). Sahin i Yildirim (2020) pišu kako su važnost područja STEM-a s vremenom prepoznale i druge zemlje među kojima ističu turski primjer, a koje su, poput Amerike, uložile prilična sredstva u njihovo osnaživanje u okviru svojih odgojno-obrazovnih sustava.

Kada je riječ o STEM-u kakvim ga danas poznajemo, treba istaknuti da se njegovo značenje s vremenom promijenilo. NSF ga je isprva definirao kao nešto širi skup kojem se osim područja prirodnih znanosti, predviđalo uključiti još društvene znanosti poput psihologije, ekonomije, sociologije te političkih znanosti (Breiner et al., 2012 prema: Green, 2007), ali očito da su po tom pitanju prevladale suženije perspektive nekih drugih agencija što sugeriraju Kocabas, Ozfidan i Burlbaw (2020). K tome, važno je napomenuti da se integrativni pristup područjima STEM-a u nastavi počeo jasnije artikulirati tek s modernijim koncepcijama (Breiner et al., 2012 prema: Labov, Reid, & Yamamoto, 2010; Sanders, 2009).

Tu integraciju (*Integrative STEM Education*) Sanders (2009) opisuje kao početno polazište jer, kako smatra, STEM u suštini nije ništa više od jednostavne kratice za četiri odvojena i različita područja kao što ni STEM u kontekstu odgoja i obrazovanja (*STEM Education*) ne označava ništa više od učenja i poučavanja u ista četiri područja na konvencionalan školski način, u okviru odvojenih nastavnih predmeta. Nasuprot tome, integraciju kao pristup područjima STEM-a u nastavi vidi kao učenje i poučavanje ispreplitanjem dvaju ili više nastavnih predmeta iz područja STEM-a i/ili ispreplitanjem nastavnih predmeta iz područja STEM-a s jednim ili više drugih nastavnih predmeta.

Važnost integrativnogq pristupa Sanders (2009) obrazlaže zapažanjem da kao što se tehnološka postignuća ne mogu odvojiti od pripadajućega društvenog i estetskoga konteksta, tako se ni učenje i poučavanje iz toga područja ne može odvajati od učenja i poučavanja u društvenom, umjetničkom i humanističkom području.

Slične težnje posljednjih godina postaju sve izraženijima u inicijativama za pridruživanjem područja umjetnosti (A) poznatom akronimu u proširenom pristupu nazvanom STEAM koji prema Seletkoviću (2017) STEM obogaćuje, između ostaloga, i stoga što odgoj i obrazovanje iz umjetničkoga područja doprinosi razvoju učenikova samopouzdanja, njegovih vještina te svakodnevnom rješavanju problema.

O STEAM-u

Uz STEAM kao naziv često stoji ime Johna Maede, svestranoga umjetnika i grafičkoga dizajnera vrlo zainteresiranoga za znanost i tehnologiju. Od 2008. do 2013. godine obnašao je funkciju ravnatelja *Rhode Island School of Design* (RISD), poznate visokoškolske ustanove koju je napustio da bi se okušao u Silicijskoj dolini.[1] Tijekom

[1] Rhode Island School of Design. *John Maeda Moves On.* (2014). https://www.risd.edu/news/stories/john-maeda-moves-on/

svojega rada u obrazovnom sustavu sa svojim kolegama na RISD-u promovirao je ideju STEAM-a argumentirajući je stavom kako STEM sam neće dovesti do značajnijih inovacija dostojnih 21. stoljeća bez njegova prožimanja s umjetnošću koja STEM-ovoj konvergenciji jasno usmjerenoj prema cilju dodaje divergentni pristup karakterističan za one koji, kako piše, profesionalno *lutaju* (Maeda, 2013).

Takva i slična nastojanja, poput onoga ranijeg Sandersova (2009), doprinijela su tzv. *STEM to STEAM* pokretu, prilično aktualnom protekloga desetljeća u SAD-u, koji je prema Ghanbari (2015) dijelom nastao i kao odraz nekih zajedničkih projekata američkih državnih agencija zaduženih za ravnopravnu promociju STEM-a i umjetnosti.

Kako je i STEAM američki pojam neodvojiv od tamošnje odgojno-obrazovne politike, u tom mu kontekstu, kao i kad je riječ o STEM-u, treba potražiti pripadajuću definiciju. Prema izvješću američke državne organizacije *Education Commision of the States* STEAM podrazumijeva pristup učenju i poučavanju kojim se promiče kritičko mišljenje i kreativnost u rješavanju problema na raskrižju prirodnih znanosti, tehnologije, inženjerstva, umjetnosti i matematike (Dell'Erba, Education Commission of the States, A. E. P. (AEP), 2019), s tim da se pod slovom A u kratici često podrazumijeva još i humanističko područje, kao što je to primjerice slučaj kod Herro, Quigley, Andrews i Delacruz (2017).

U spomenutom američkom izvješću dalje stoji kako problemi koji se na taj način rješavaju izviru iz interesa i svakodnevnoga okružja učenika i studenata, a njegova je jedinstvena vrijednost transdisciplinarno mišljenje koje se razvija stapanjem analitičkoga mišljenja (najčešće vezanoga uz STEM) i kreativne ekspresije (najčešće vezane uz umjetnost) u svrhu stvaranja inovacije.

Pritom se u izvješću naglašava kako STEAM podrazumijeva integraciju različitih područja, ali tako da svako područje pritom zadržava svoju samostalnost dok konačni rezultati do kojih se takvim pristupom dolazi ne pripadaju ni jednom od spomenutih područja isključivo.

Upotpuni li se takav opis s istraživanjima u praksi o kojima pišu Bertrand i Namukasa (2020) te Liao (2016), STEAM-u se može pridodati još jedna bitna kvaliteta, a to je kreativni proces koji takvim pristupom osobito dolazi do izražaja.

Ipak, treba primijetiti kako je vezanje područja STEM-a uz razvoj analitičkoga mišljenja, a umjetnosti uz razvoj kreativnoga što je vidljivo i u Maedeovu (2013) promišljanju, prilično pojednostavljeno shvaćanje jer ni analitičko mišljenje, a ni ono kreativno, onda ni kreativni procesi, ne pripadaju ekskluzivno jednom području.

Spomenuto raščlanjivanje analitičkoga i kreativnoga mišljenja po područjima Sousa i Pilecki (2018) objašnjavaju uvriježenim predodžbama o znanstvenicima, matematičarima i inženjerima kao logici, analizi i preciznosti sklonim individualcima dok se na umjetnike gleda kao na one kreativne, sklone holističkom pristupu i vizualizaciji. Te predrasude poduprle su dodatno, smatraju isti autori, pogrešne interpretacije istraživanja o funkcijama lijeve i desne polutke mozga koje se često u javnosti apstrahiraju do podjele ljudi na taj način, premda razmišljanje, učenje i

ponašanje pojedinca nije dominantno određeno ni *analitičkom* lijevom ni *vizualnom* desnom polutkom. I jedna i druga simultano sudjeluju u procesuiranju ogromne količine informacija svakodnevno te radeći zajedno pružaju uvid u cjelovitu sliku onoga što se oko nas događa.

Uz to, *kreativnu* umjetnost vjerojatno treba promatrati i kao pokušaj afirmacije njezine uloge u odgoju i obrazovanju koja je prema Zimmeru (2019), uz onu humanističkih znanosti, u SAD-u u drugom planu u odnosu na STEM koji se veže uz poslovni svijet te ga se stoga tradicionalno više podupire.

Ako se osvrnemo na suvremenu ekonomiju i nove atraktivne profesije koje mlađe generacije sve više zanimaju, a koje i američka komisija spominje u svojem izvješću, poput animacije, dizajna, urbanoga planiranja, područja zdravstva (različitih vrsta terapija, ali i područja biomedicinskoga inženjeringa, dentalne medicine, plastične kirurgije...), audioinženjerstva, razvoja računalnih igara... (Dell'Erba et al., 2019), jasno je kako umjetnost danas ne treba podupirati samo zbog njezine zapostavljenosti u odnosu na druga područja u odgojno-obrazovnim sustavima, nego i radi njezina izrazitoga gospodarske važnosti.

Taj gospodarski značaj umjetnosti sadržan je dijelom i u sintagmi kreativnih industrija koje uključuju već spomenute arhitekturu, dizajn, računalne igre/ nove medije…, a koje Jobst (2020) opisuje kao dominantno područje interesa 21. stoljeća. Doduše, ona pritom napominje kako se kreativne industrije u Hrvatskoj još uvijek nalaze u fazi formalnoga ustroja, ali da se ulažu napori kako bi se prepoznala važnost toga sektora.

Pozitivan primjer tih nastojanja sigurno je brzorastuća djelatnost vezana uz razvoj računalnih igara kojoj su već posvećeni neki odgojno-obrazovni programi, poput onih srednjoškolskih u Sisku i Novskoj.

STEAM, suradnja i transdisciplinarnost

S obzirom na to da je STEAM relativna novina u odgoju i obrazovanju, ne ostaje bez upitnika. Neki mogu proizlaziti iz poteškoća vezanih uz osmišljavanje provođenja takvoga pristupa u nastavnoj praksi, odnosno iz određivanja profila učitelja adekvatnih za provođenje takve nastave.

Sousa i Pilecki (2018) u svojoj se knjizi prvenstveno obraćaju (američkim) učiteljima iz područja STEM-a podupirući njihovu težnju za uključivanjem umjetnosti u svoju nastavu, ali naglašavajući pritom da je u srcu STEAM-a ipak suradnja. Suradnju kao oblik planiranja nastave, poučavanja i učenja oni prvenstveno vežu uz umjetničko područje, konkretno uz glazbu i scensku umjetnost koje u svojim izvedbama ovise o stručnjacima iz različitih područja.

Da je suradnja kvalitetno polazište, naglašavaju još Herro i ostali (2017) koji je opisuju kao jednu od važnih vještina 21. stoljeća, prikladnu za razvoj ranije spomenutoga transdisciplinarnog mišljenja kojim se teži cjelovitom sagledavanju problema i njegovom rješavanju potrebnim kompetencijama iz različitih područja. U skladu s time pod STEAM-om oni podrazumijevaju suradnički pristup u rješavanju problema

čemu sigurno doprinose spomenute kompetencije iz svakoag pojedinog područja ugrađenoga u kraticu, ali i projektno učenje, uporaba tehnologije u kreativne svrhe te divergentni pristup.

Opisano polazište u problemu, ne u područjima, smatraju u metodičkom smislu onom bitnom razlikom između transdisciplinarnoga i, recimo, multidisciplinarnoga pristupa koji se često organizira tematski (Herro et al., 2017 prema: Wickson et. al, 2006), a primjer toga u hrvatskom školstvu bili bi projektni dani.

Slično te razlike opisuje Cerovac (2013) svrstavajući i multidisciplinarnost i interdisciplinarnost u disciplinarne pristupe jer ili označavaju zajednički rad stručnjaka iz različitih područja pri čemu se svaki od njih drži svojih pristupa i pogleda (multidisciplinarnost), ili se zajednički angažiraju na mjestima na kojima se njihova područja presijecaju, pa se to onda može shvatiti i kao izgradnja zajedničkoga modela za uključene discipline (interdisciplinarnost).

Nasuprot tome, transdisciplinarnost Cerovac (2013: 20) opisuje kao integrativno istraživanje koje *povlači za sobom višu fazu međudjelovanja*. Istražujući na ovaj način, stručnjaci iz različitih područja, zajednički i sveobuhvatno doprinose rješavanju istoga problema, ali tako da se pritom ne poništava važnost ni jednoga područja pojedinačno.

Prednosti transdisciplinarnoga mišljenja koji omogućuju takvo kreativno prenošenje informacija iz jedne domene u drugu su, pišu Mishra, Henriksen i *The Deep-Play Research Group* (2012), specifične kognitivne vještine poput percepcije, uzorkovanja, apstrakcije, utjelovljenoga mišljenja (*emboided thinking*), oblikovanja, igre i sinteze, a koje možemo povezati i sa znanošću i s umjetnošću.

Ne čudi stoga što isti autori svoja razmatranja o transdisciplinarnom mišljenju vežu uz integrativni pristup STEM-u u nastavi, onda i u STEAM-u, ali naglašavajući kako nas ono, barem što se tehnologije kao njihova glavnoga interesa tiče, može odvesti i mnogo dalje.

Naravno da nepregledne mogućnosti bude entuzijazam, ali istovremeno mogu stvoriti osjećaj nesigurnosti. Ta se nesigurnost kod STEAM-a očituje u određenim otporima. Zimmer (2019) piše da neki pobornici STEM-a u nastavi smatraju kako bi ih inzistiranje na uvođenju novih područja u postojeće okvire moglo omesti u ostvarivanju zadanih ishoda kao i to da oni, i bez imperativa slova A u starijem akronimu, umjetnost u svoju nastavu već uvode, kada im je to potrebno u svrhu realizacije određenoga projekta iz područja STEM-a.

Nadalje, prema STEAM-u su kritični i neki pedagoški djelatnici iz umjetničkoga područja po kojima umjetnosti u STEM-u jednostavno nema mjesta, pri čemu ističu njezinu autonomiju. K tome, značajan je broj onih koji prema STEAM-u naprosto ostaju indiferentni jer im je nejasna njegova svrha (Zimmer, 2019).

Taj posljednji argument prilično je jak, osobito kada ga se promatra u odnosu na STEM koji se često poima natjecateljski, pa se onda i uspješnost njegove integracije u odgojno-obrazovne sustave pojedinih zemalja u znanstvenim istraživanjima nerijetko direktno veže uz rezultate PISA testova dok su glavne vrijednosti STEAM-a, poput cjelovitog sagledavanja problema, teže mjerljive na taj način.

Na kraju, osim na spomenute otpore pozornost treba usmjeriti i na prvi pogled pozitivne inicijative koje Zimmer (2019) isto spominje, a koje ulogu umjetnosti u STEM-u vide kao svojevrsno sredstvo privlačenja učenika u ta područja. U suštini gledano, takav pristup može imati efekta, no treba imati na umu da je umjetnost mnogo više od omekšavanja učenikova pogleda na neka *ozbiljnija* područja.

STEAM iz perspektive hrvatskoga odgojno-obrazovnoga sustava

Prije razmatranja mogućnosti STEAM-a u hrvatskim školama treba se još jednom kratko osvrnuti na one američke škole u kojima je integracija umjetnosti u nastavu (*Arts Integration*) već dugo prisutan model te se i STEAM, kako pišu Sousa i Pilecki (2018), može promatrati u liniji iste kronologije.

Takvu integraciju treba razlikovati od konvencionalnih nastavnih predmeta iz umjetničkoga područja po tome što ona, prema definiciji Centra izvedbenih umjetnosti John F. Kennedy u Washingtonu (involviranoga u tu priču od 1976. godine), predstavlja pristup učenju i poučavanju kojim učenici demonstriraju svoje razumijevanje drugih nastavnih sadržaja u umjetničkoj formi. U takvom kreativnom procesu uočavaju veze između jednog i drugog te ostvaruju ciljeve koji pripadaju jednome i drugome (Duma & Silverstein, 2014).

Kao one koji su jačanju takvoga pristupa dali značajan doprinos, Sousa i Pilecki (2018) ističu Howarda Gardnera i njegov model višestrukih inteligencija te Maxine Greene koja se snažno zalagala za uvođenje umjetnosti u nastavu.

Relativno nedavno, 2015. godine, takvu je integraciju u SAD-u nanovo aktualizirao opsežni zakon *Every Student Succeeds Act* (ESSA) u čijim se točkama umjetnost opisuje kao sastavni dio kvalitetno zaokruženoga odgojno-obrazovnoga procesa, a u čemu Dell'Erba (2020) opet vidi mogućnosti za primjenu STEAM-a.

Ukratko, i STEM i STEAM, a i *Arts Integration* izrasli su iz jednoga specifičnog odgojno-obrazovnoga kontekstu koji se razlikuje od hrvatskog i kojeg nije uvijek lako razumjeti. Kada je riječ o STEM-u, nije uzgred spomenuti to da se kao nulti događaj u njegovoj povijesti često spominje lansiranje sovjetskoga Sputnika u orbitu 1957. godine (Donnelly, 2019), što mnogo govori o njegovoj početnoj motivaciji. Osvrnemo li se pak na STEAM i *Arts Integration*, lako je pretpostaviti da te inicijative, koje proizlaze iz umjetničkoga područja i podršku daju umjetnosti, imaju barem neke veze s time što financiranje javnih škola u SAD-u nije ujednačeno i što, kada dođe do krize, umjetnost prva nastrada (Thompson, 1994; Gregory, 2017).

Nezavidna satnica nastavnih predmeta iz umjetničkoga područja u hrvatskim osnovnim školama te u onim srednjim školama koje nastavu vezanu uz to područje uopće sadrže, kao i uz to vezan nezavidan status takvih predmeta, problem je s kojim se susreću i naši pedagoški djelatnici iz umjetničkoga područja. Što se ovoga konkretnog istraživanja tiče, treba priznati da je taj problem bio i glavni poticaj istraživanju STEAM-a kao jedne

od mogućnosti prevladavanja trenutačnoga statusa umjetnosti, ali i njezina pomicanja prema tržištu, osobito kada je riječ o području likovnih i vizualnih umjetnosti. Takvo propagandno polazište koje se kretalo od afirmacije jednoga područja, naravno da je tijekom istraživanja zamijenila drugačija perspektiva, jer je STEAM-u, kako je već prethodno napisano, najvažnije riješiti problem. U tom su mu smislu od pojedinačnih disciplina bitnije veze koje se između njih mogu ostvariti u svrhu njegova rješavanja. Istovremeno, veze su nešto što je u hrvatskom odgojno-obrazovnom sustavu itekako prisutno, a što bi značilo da i za STEAM, kao i za svaki drugi integrativni koncept, postoji podatan zakonski okvir.

Usmjeri li se pažnja na likovne i vizualne umjetnosti, onda i pripadajući osnovnoškolski nastavni predmet Likovna kultura u hrvatskom odgojno-obrazovnom sustavu, poželjna praksa međupredmetnoga povezivanja u obliku korelacije, i to one strukturalne, kojoj se pridavala prednost pred tematskom, bila je jasno istaknuta još u *Nastavnom planu i programu za osnovnu školu u Republici Hrvatskoj* (NN, 102/2006) kao prijašnjem krovnom dokumentu za izvođenje nastave. Razlog isticanju strukturalne korelacije vjerojatno leži u nastavi često prisutnom ilustrativnom poimanju umjetnosti u njezinu ispreplitanju s drugim područjima pri čemu se, kako piše Huzjak (2016), likovnost svodi na motiv koji se prikazuje dok se zanemaruje njezin likovni sadržaj.

Za razliku od Likovne kulture kod koje je naglasak na likovnom i vizualnom izražavanju učenika, kod srednjoškolskoga nastavnog predmeta Likovna umjetnost u fokusu je sustavno istraživanje likovne i vizualne umjetnosti čime se težište s umjetničkoga prebacuje na humanističko područje. Taj pomak na prijelazu iz osnovne u srednju školu učenika s jedne strane udaljuje od praktičnoga rada, ali mu zato otvara neke druge mogućnosti sagledavanja umjetničkoga djela pri čemu se uslojava njegova kontekstualna vrijednost, jasno istaknuta još u *Nastavnim programima za gimnazije* (Glasnik Ministarstva kulture i prosvjete, 1994), dokumentu kojim se predlažu konkretne mogućnosti međupredmetnoga povezivanja, ne samo s drugim predmetima iz umjetničkoga i humanističkoga područja nego i s predmetima iz područja STEM-a, preciznije Matematikom te Fizikom i Kemijom. Ne smije se zanemariti ni u dokumentu spomenuta važnost Tjelesne i zdravstvene kulture kojoj bi se iz današnje perspektive slobodno mogli priključiti još biologija kao prirodna znanost te cijeli spektar društvenih znanosti, tehničko područje… Ali i ono što je u tom tekstu navedeno mnogo govori o široko postavljenim okvirima učenja i poučavanja koji u hrvatskim službenim dokumentima postoje već dugo.

S novim predmetnim kurikulima iz 2019. godine međupredmetna je povezanost, kao i povezanost nastavnih predmeta sa sedam međupredmetnih tema, još više naglašena te se, kada je o Likovnoj kulturi i Likovnoj umjetnosti riječ, ogleda već u nazivima obveznih i izbornih predmetnih tema predviđenih za obradu. Dovoljno je spomenuti tek pokoju, poput *Prirode i oblika* i *Umjetnosti i zajednice* koje od prvog razreda osnovne škole umjetnosti nastoje pristupiti u relaciji s drugim područjima (NN, 7/2019).

Radionica *STEM i ART idu skupa!* Kao istraživanje STEAM-a u praksi

Radionica *STEM i ART idu skupa!* u okvirnom trajanju od jednog i pol sata održana je 11. travnja 2019. godine u prostoru Novog kampusa Sveučilišta u Zadru s tadašnjim studentima. Radionici je prisustvovalo dvanaest sudionika, jedanaest studenata četvrte godine učiteljskoga studija Odjela za izobrazbu učitelja i odgojitelja Sveučilišta u Zadru (deset studentica i jedan student) i jedna studentica s drugoga odjela istoga Sveučilišta. Radionica je bila dio programa 17. Festivala znanosti s temom *Boje*, a osmislile su je i vodile doc. dr. sc. Maja Cindrić i autorica članka.

Radionica se bazirala na istraživanju interaktivne umjetničke instalacije poznatoga umjetnika Olafura Eliassona pod naslovom *Your uncertain shadow (colour)* iz 2010. godine, s tim da ni umjetnik ni umjetničko djelo nisu odabrani bez razloga. Eliasson je umjetnik koji u svojem radu redovito surađuje s velikim brojem stručnjaka iz različitih područja, a tako je bilo i prije nego što je izveo spomenutu instalaciju. U uvodnom dijelu jednog intervjua iz 2009. godine piše kako u svom berlinskom studiju radi s tridesetak arhitekata, arhivista, umjetnika, majstora… te se kao odgovor na pitanje zašto radi s tolikim stručnjacima navodi njegov citat koji bi otprilike glasio: *Ja stvaram djela, ali trebam nekoga tko bi ih sa mnom sagledao. Trebam drugoga kako bih se uvjerio da svijet postoji.* (Peter & Eliasson, 2009: 34).

Osim suradnje kao konstante, uz STEAM ga veže još nešto, a to je njegov interes za prirodne fenomene. U istom intervjuu to se posebno očituje u dominantnoj temi svjetla što ne čudi s obzirom na slavu koju je stekao svojom instalacijom *The weather project* predstavljenom u londonskom Tate Modernu 2003. godine. Uz svjetlo Eliasson u razgovoru najavljuje pokret kao jedan od svojih interesa za budućnost, a upravo su svjetlo i pokret sastavni dijelovi njegove instalacije *Your uncertain shadow (colour)* čija se fotodokumentacija i formalni opis mogu pronaći na autorovim službenim mrežnim stranicama. Pojednostavljeno, tu instalaciju čine obojana svjetla poredana po podu paralelno s bijelim zidom. Prazan prostor između namijenjen je posjetiteljima koji, kada njime prolaze, stvaraju nizove raznobojnih sjena na zidu.

Svrha i ciljevi istraživanja, istraživačka pitanja

Svrha istraživanja bila je u praksi istražiti mogućnosti STEAM-a u nastavi osmišljavanjem i realizacijom takvih aktivnosti kojima bi se u kratkom vremenu studentima on prezentirao kao jedan od mogućih integrativnih pristupa.

Cilj istraživanja bio je posredstvom Eliassonove instalacije i u suradnji s polaznicima radionice na poticajan način pristupiti aditivnom miješanju boje, onda i njegovim vezama sa suptraktivnim miješanjem boje kao temama koje su bliske i znanosti i umjetnosti.

U skladu sa svrhom i ciljem istraživanja formirana su sljedeća istraživačka pitanja:

1. Doprinosi li istraživanje Eliassonove instalacije iz različitih perspektiva, umjetničke i znanstvene, slojevitijem doživljaju i kvalitetnijem razumijevanju toga umjetničkog djela?

2. Doprinosi li istraživanje Eliassonove instalacije iz različitih perspektiva, umjetničke i znanstvene, kvalitetnijem razumijevanju aditivnoga miješanja boje kao prirodnoga fenomena koji se iz znanstvene perspektive može objasniti i bez istraživanja umjetničkoga djela?
3. Doprinosi li rekonstrukcija Eliassonove instalacije u uvjetima učionice kvalitetnijem razumijevanju veza između aditivnoga i suptraktivnoga miješanja boje?
4. Doprinosi li izvedba likovnih radova prema Eliassonovoj instalaciji, onda i usporedna analiza izvedenih likovnih radova s Eliassonovom instalacijom, razlikovanju aditivnoga i suptraktivnoga miješanja boje, onda i CMYK sustava i osnovnih boja prema Ittenovu krugu od kojih se obično polazi u Likovnoj kulturi?

Navedena četiri pitanja vezana su uz konkretne aktivnosti koje su bile planirane radionicom, a u suštini izviru iz onoga najvažnijeg istraživačkog pitanja navedenoga u nastavku, a koje neposredno proizlazi iz svrhe i cilja istraživanja:

Može li se istraživanjem Eliassonove instalacije, onda i aditivnoga i suptraktivnoga miješanja boje doprinijeti uočavanju snažne povezanosti između umjetnosti i znanosti?

Metodologija

Istraživanje je bilo zamišljeno kao kvalitativno, vezano uz odgojno-obrazovni kontekst iz kojeg onda potječu i metode koje su se u njemu koristile.

S obzirom na to da je okosnicu osmišljene i realizirane radionice predstavljalo umjetničko djelo, kao glavnu metodu korištenu u istraživanju treba istaknuti metodu estetskoga transfera, specifičnu za područje likovnoga i vizualnoga odgoja i obrazovanja. Riječ je o osobitom pristupu umjetničkom djelu čija se osnovna struktura može elegantno ugraditi u svaki nastavni sat Likovne kulture. Prema Duhu i Zupančiću (2011) čine je percepcija (percepcija umjetničkoga djela svim osjetilima), recepcija (iskazivanje slika riječima) i reakcija (aktivnost, produktivna reakcija na umjetničko djelo). Kod metode estetskoga transfera te su tri faze usmjerene prema stjecanju novoga estetskog iskustva kao krajnje vrijednosti koja se tom metodom može postići.

Od specifičnih odgojno-obrazovnih metoda vezanih uz prirodne znanosti treba istaknuti pokus (eksperiment) vezan uz rekonstrukciju umjetničkoga djela u uvjetima učionice.

Uz spomenute metode u realizaciji radionice rabile su se još neke koje nisu specifične za pojedina područja, poput razgovora i izlaganja.

Što se tiče likovnih radova kao materijalnih produkata istraživanja, s polaznicima radionice analitički im se pristupilo neposredno nakon njihova dovršetka. Uz to treba naglasiti da dio zaključaka iz rasprave o rezultatima istraživanja proizlazi iz njihove interpretacije.

Plan istraživanja

Kada se radionica prijavljivala za Festival znanosti, njome se, onda i istraživanjem, planiralo sljedeće:

1. istraživanje Eliassonove instalacije i Eliassona kao umjetnika na načine specifične za nastavne predmete Likovna kultura i Likovnu umjetnost
2. rekonstrukcija njegove instalacije u uvjetima učionice u obliku pokusa karakterističnoga za prirodne znanosti
3. analiza izvedenoga pokusa iz perspektive fizike i fizikalne optike
4. realizacija likovnih zadataka (likovnih redefinicija Eliassonove instalacije u kolažu kao slikarskoj likovnoj tehnici) grupnim oblikom rada
5. refleksija na provedene aktivnosti i izvedene likovne radove
6. analiza rezultata tako provedenog istraživanja.

Realizacija istraživanja

U realizaciji istraživanja je u biti došlo se do rezultata kojima se težilo uz prethodno navedeni plan, no uz male izmjene u redoslijedu, s time da je tijekom njegove provedbe do izražaja vrlo brzo došlo nešto što propagira i STEAM – da se umjetničko i znanstveno područje ne mogu jasno podijeliti po točkama. Na održanoj radionici te su se perspektive od početka počele ispreplitati i prožimati.

Studentima je na radionici prvo bila prikazana fotodokumentacija, potom i videodokumentacija Eliassonove instalacije pri čemu ih se pokušalo navesti da opišu ono u što gledaju. Kada su zaključili da je u pitanju umjetničko djelo koje uključuje svjetlo, boju, sjene, posjetitelje… istražili su zajedno s voditeljicama Eliassona kao umjetnika, a osobito njegov interes za prirodne fenomene o kojima je, kako su zaključili, i kod *Your uncertain shadow (colour)* riječ.

Studente se potom kratko podsjetilo na prirodu svjetlosti, onda i na način na koji vidimo boje, a s čime su se tijekom svojega osnovnoškolskog i srednjoškolskog odgoja i obrazovanja sigurno već susreli, osobito u okviru nastavnih predmeta vezanih uz STEM. Nakon opisanoga prišli su pokušaju rekonstrukcije Eliassonova djela u uvjetima učionice pomoću tri džepne svjetiljke prekrivene transparentnim folijama u crvenoj, zelenoj i plavoj kao osnovnim aditivnim bojama (RGB).

Kada su studenti svoja obojana svjetla usmjerili u bijeli zid, potvrdili su prvo ono poznato, a to je da osnovne aditivne boje zajedno daju bijelu svjetlost kao i to da međusobnim preklapanjem svake dvije od spomenutih boja nastaju osnovne boje suptraktivnoga miješanja. Prolaženjem između izvora svjetlosti i zida, a pri čemu su se na zidu počele *čarobno* pojavljivati raznobojne sjene, postala im je jasna i strukturalna međuovisnost prirodnih zakona i Eliassonove umjetničke vizije.

Uspoređujući usmjerenije Eliassonovu instalaciju sa svojom rekonstrukcijom opazili su još nešto. Primijetili su da, iako su efekti i jednoga i drugoga analogni, ipak se razlikuju, i to stoga što se Eliasson u svojoj instalaciji nije poslužio trima osnovnim aditivnim bojama, nego je na podu strateški rasporedio čak pet svjetala - dva zelena jedno pored drugoga, zatim *magenta*, narančasto i plavo svjetlo koja su zajednički isto

rezultirala obasjavanjem nasuprotnoga zida bijelom svjetlošću.[2] Prema tome, zaključili su da su mogućnosti manipulacije, onda i kreativnoga pristupa aditivnom miješanju boje velike te to odmah povezali sa scenskom umjetnošću, ali i drugim područjima, primjerice filmom.

Slika 1. Ilustracije provedene rekonstrukcije Eliassonove instalacije u uvjetima učionice (privatni album).

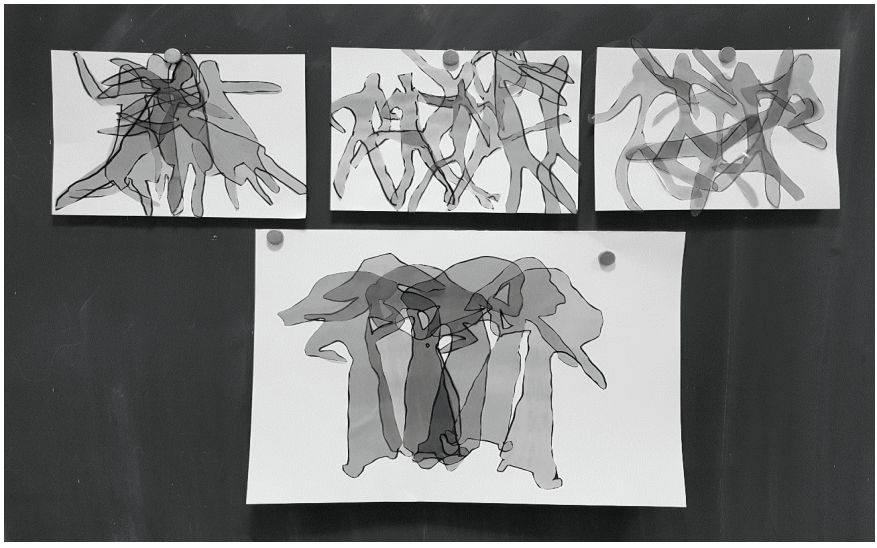
Vezano uz njihovo buduće zanimanje učitelja, sa studentima se razgovaralo o tome kako bi oni ove zaključke vezane uz boju kao svjetlost usporedili s mogućnostima miješanja boje kao pigmenta na papiru. Podsjetilo ih se na osnovne suptraktivne boje na zidu koje su dobili preklapanjem osnovnih aditivnih, onda i na način na koji funkcionira pisač i koju ulogu u tome imaju njegove CMYK patrone. Sve spomenuto usporedili su s osnovnim bojama Ittenova kruga (crvenom, žutom i plavom) od kojih se obično polazi u Likovnoj kulturi te zaključili kako se do raznovrsnih koloristićkih vrijednosti može doći na više načina.

Potom su pristupili redefiniranju Eliassonova djela u slikarskoj likovnoj tehnici kolaža, i to lijepljenjem transparentnih folija u crvenoj, žutoj i plavoj boji na bijeli papir. Pritom nisu zaboravili da izrezani oblici trebaju reflektirati multiplicirane sjene ljudskih figura u svrhu čega su prvo izradili figurice od žice i aluminijske folije okvirno odgovarajućih proporcija (koje su izvodili iz osnovnoga omjera visine glave i visine ljudskoga tijela (1:7)), da bi zatim na suradnički način od tih figurica i pomoću svjetiljki crtali obrise obojanih sjena na folijama, i to tako da bi kod crtanja svakoga novog obrisa svoje figurice malo pomaknuli u svrhu dočaravanja pokreta. Na kraju su dobivene obrise izrezivali i lijepili na papir.

[2] Olafur Eliasson. *Your uncertain shadow (colour).* 2010. Preuzeto 30. 1. 2021. s: https://olafureliasson.net/archive/artwork/WEK100100/your-uncertain-shadow-colour#slideshow

Slika 2. Studenti stvaraju svoje redefinicije Eliassonove instalacije u likovnoj tehnici kolaža (privatni album).

Radionica se tako privela kraju onime čime je i započela, plošnim prikazima obojanih silueta, ali s jednom bitnom razlikom – studenti su na kraju radionice bili itekako svjesni onoga u što gledaju kao i transformacije koja se putem dogodila.



Slika 3. Studentski likovni radovi izvedeni na radionici (privatni album).

Rasprava o rezultatima

Iako su prikazani likovni radovi kao materijalni produkti proizašli iz radionice samo djelomični rezultati provedenoga istraživanja, predstavljaju njegov važan dio budući da se istraživanje, koje isprva nije bilo ambicioznije zamišljeno, nije planiralo popratiti opsežnijom dokumentacijom. Stoga, uz opisano u poglavlju *Realizacija istraživanja*, doprinose odgovorima na prethodno postavljena istraživačka pitanja.

Na prvo pitanje, a koje se tiče korisnosti istraživanja za doživljaj i razumijevanje umjetničkoga djela, može se odgovoriti kako je opisani pristup doprinio njegovom slojevitijem doživljaju i kvalitetnijem razumijevanju. No, treba naglasiti kako je radionicom kvalitetno obuhvaćen samo jedan aspekt te umjetničke instalacije, a to je svjetlost. Što se tiče pokreta, polaznicima se nije uspjelo odabranim metodama rada u kratkom vremenu sustavnije približiti tu osobitost Eliassonove instalacije. Vidljivo je to iz prikazanih likovnih radova koji posjeduju potrebna kolористička preklapanja, ali kompozicijski nisu osmišljena tako da dočaravaju ritmičan sklad pokreta. Vjerojatno bi za uspješno savladavanje toga aspekta instalacije potrebniji bio duži vremenski period za njezino istraživanje, onda i realizaciju likovnih radova, a sigurno bi korisna bila i suradnja sa stručnjacima iz područja izvedbenih umjetnosti ili možda kineziologije.

Drugo istraživačko pitanje, koje se tiče razumijevanja aditivnoga miješanja boje posredovanjem istraživanja umjetničkoga djela, nije takvo da se na njega može jednoznačno odgovoriti. Ipak, na temelju iznenađenja polaznika radionice koje je nastupilo uočavanjem vizualnih efekata nastalih izvedbom jednostavnoga pokusa, ali tek nakon fokusiranoga istraživanja Eliassonove instalacije, može se zaključiti kako je ovakav pristup svakako poticajan u odgojno-obrazovnom kontekstu. Pa i činjenica jest kako pokus nije taj koji je potaknuo osmišljavanje radionice nego umjetničko djelo. Naime, uloga umjetnosti kao one koja skreće pažnju na nešto što nam je poznato do te mjere da to više uopće ne primjećujemo vrlo je važna. Eliasson je te njezine uloge itekako svjestan te je u svojem radu redovito koristi podsjećajući nas uvijek iznova na to koliko su čvrste veze između vizualnih, općenito osjetilnih kvaliteta koje nam objašnjavaju prirodne znanosti i estetike.

Što se tiče odgovora na treće i četvrto istraživačko pitanje, a koja se odnose na doprinos istraživanja kvalitetnijem razumijevanju veza, onda i razlika između istraženih načina miješanja boje, ono je tome apsolutno pridonijelo. Taj je podatak važan jer je, praktično gledano, korisnost od uočavanja različitih vidova boje kod budućih učitelja velika. Naime, već se u prvom razredu kurikulskim sadržajima prvoga ishoda domene *Stvaralaštvo i produktivnost* u Likovnoj kulturi (LK A.1.1.) navode i dugine boje, ali i osnovne i izvedene boje (NN, 7/2019). To bi značilo da od samoga početka školovanja do izražaja dolaze dva njezina vida; boja kao svjetlost i boja kao pigment, a o čemu treba voditi računa u nastavnoj praksi.

Konačno, odgovor na pitanje može li se ovakvim istraživanjem doprinijeti uočavanju snažne povezanosti između umjetnosti i znanosti svakako je potvrdan, s tim da treba

napomenuti kako je ovo istraživanje samo jedna mala ilustracija te povezanosti. Naime, održana radionica bila je pokaznoga karaktera, zamišljena tako da se njome studente, buduće učitelje, upozna sa STEAM-om kao integrativnim pristupom koji bi mogli koristiti u svojoj nastavi. Te okolnosti kao i kratko vrijeme predviđeno za njezinu realizaciju, i to u okviru festivala kojem je jedan od važnih ciljeva popularizacija znanosti u široj populaciji, utjecali su na to da je bila naglašeno vođena, a što je vidljivo i iz prikazanih likovnih radova.

Da se radionica održavala u etapama, voditeljice bi joj pristupile mentorski i općenito bi veći naglasak bio na istraživačkom pristupu kao što bi i sam cilj, onda i ishodi bili postavljeni složenije. No, i u kratkom vremenskom okviru do izražaja je došlo nešto vrlo bitno, a to je da se aditivno miješanje boje, a čemu se često u razredu pristupa udžbenički, pomoću nekoliko shematskih slikovnih prikaza, može pretočiti u jedinstveni doživljaj koji u nastavi može biti produktivna ishodišna točka kreativnoga procesa karakterističnoga baš za STEAM.

Zaključak

STEAM kao odgojno-obrazovni pristup koji uključuje područja STEM-a i umjetnost te humanističko područje prvenstveno proizlazi iz specifičnosti odgojno-obrazovnoga sustava SAD-a što treba imati na umu prilikom istraživanja mogućnosti njegove primjene u nekom drugom kontekstu.

Svejedno, istraživati ga svakako vrijedi jer osim karakteristika vezanih uz svoje izvorište STEAM posjeduje mnoge univerzalne vrijednosti. U tekstu je poseban naglasak stavljen na suradnju u rješavanju problema, transdisciplinarnost i kreativni proces. Takav STEAM, podržavajući ono najbolje od područja koje obuhvaća, a koja se često stereotipno svrstavaju na suprotne strane, u sebi sadrži nešto od ideje renesansnoga čovjeka, sklonoga cjelovitom sagledavanju izazova s kojima se susreće. Općenito gledano, to je njegova najveća vrijednost koja je danas itekako na cijeni s obzirom na zanimanja iz domene kreativnih industrija privlačnima mlađim generacijama.

Vezano uz hrvatski odgojno-obrazovni sustav, vrata STEAM-u su, kao i svakom drugom integrativnom pristupu, širom otvorena, osobito polazi li se od važećih predmetnih kurikula koji apsolutno računaju na međupredmetno povezivanje, s tim da treba istaknuti kako se ono njegovalo još ranije, u starijim krovnim dokumentima. Prema tome, predmetne učitelje i nastavnike treba ohrabrivati u njihovim nastojanjima za primjenom STEAM-a u svojoj nastavi kada im se za to ukaže prilika, već u skladu s ishodima koji ih predmetnim kurikulima obvezuju i s obzirom na organizacijske mogućnosti koje se od škole do škole razlikuju.

U ovakvom, ali i drugačijim integrativnim pristupima, osobito treba poticati učitelje razredne nastave čijim je budućim kolegama bila posvećena u tekstu opisana radionica kao primjer istraživanja STEAM-a u praksi. Povezivanje sadržaja u njihovom je slučaju ono što se nameće činjenicom da učenika paralelno prate u njegovim ranim susretima s različitim područjima znanosti i umjetnosti.

STEAM im u tom smislu može biti poticajan jer, kako je istraživanje pokazalo, već u skromnom obimu uslojava veze između znanosti i umjetnosti, i to tako da nam se ta područja čine bližima nego kada ih sagledavamo kao zasebna, izdvojena iz konteksta. Ipak, prilikom opredjeljenja za STEAM više je stavki na koje bi trebalo paziti.

Kao prvo, takvu bi integraciju trebalo kvalitetno osmisliti, svaki put odabirom onih tema, problema i primjera kod kojih komplementarnost određenih sadržaja iz područja znanosti i umjetnosti više dolazi do izražaja. Paralelno s time korisno bi bilo ustrajati na ostvarivanju produktivne suradnje s drugim stručnjacima u svrhu obogaćivanja i funkcionalnijega povezivanja tih sadržaja. Uz navedeno još bi bilo potrebno voditi računa o nastavnim metodama jer STEAM nije hermetičan. Štoviše, izrazito je procesualnoga karaktera što bi značilo da istovremeno *živi* i od načina na koji se osmišljava i provodi kao i od svojih krajnjih rezultata. Stoga se njegovu vrijednost ne bi ni smjelo procjenjivati samo na temelju materijalnih produkata koji iz neke aktivnosti proizlaze. Oni u svakodnevnoj nastavnoj dinamici prije svega služe refleksiji u svrhu poboljšanja.

Na kraju se treba osvrnuti na STEAM kao pitanje odgojno-obrazovnoga trenda jer sve u tekstu napisano, a vezano uz način na koji se uopće artikulirao na to upućuje. STEAM se zaista može pojmiti kao trend, ali to ne znači da je površan kao što ni druge, još novije inicijative poput STREAM-a (STEAM + *Reading*) to nisu. Prije se mogu shvatiti kao entuzijastični pokušaji kojima se težište s disciplinarnih pristupa nastoji prebaciti na funkcionalne uloge pojedinih disciplina u rješavanju zajedničkih problema. Kada se taj način razmišljanja primijeni na nastavu, rješavanje problema brzo se preobražava u kreativni proces, ponekad i pomalo *krivudav*, ali koji nastavu svaki put čini osobitim iskustvom.