"Developing Interdisciplinary Instructional Design Through Creative Problem-Solving by the Pillars of STEAM Methodology"

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Abstract. STEAM methodology proposes a holistic view of educational topics and provides the tools and structures so as to combine them in everyday school practice. Science, Technology, Engineering, Arts and Mathematics are the five silos, through which each topic is explored. Arts, as the new extension, is considered to be the key in bringing technological topics closer to social and humanity sciences, in order to design real inter-disciplinary teaching and learning experiences. STEAMapT^{2}theGalaxy course aims to provide a proper e-learning environment so as to enable participants to manage to use STEAM activities in practice through problem-solving procedures that they design by themselves.

Keywords: STEAM · Creative Problem Solving · Six Thinking Hats Creativity · Inter-disciplinary

1 Introduction

E-learning is a necessity that education coordinators need to embrace in order to achieve better learning results and more importantly to facilitate learning opportunities that expand over the traditional classroom's walls. In addition, the ever-changing learning environment that modern societies tend to face, makes the skills of adaptation and problem-solving come to the foreground.

1.1 The Research Background and Motivation

The detailed consideration of the current research proposals, concluded to the two major factors that issued the research gap - the need of altering the way science is being approached in education today and the challenge of developing problem-solving skills throughout education. The previous statements are explained in detail below:

It is common sense that rational and divergent thinking are not to be separated in the fields of education. Opposite to this admission, STEM subjects tend to be combined to the convergent thinking and that is why the initial STEM methodology is criticized

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of being a technocratic teaching approach. On the other hand, research through the ages, beginning from the important influential personalities, such as Leonardo da Vinci, to the more recent findings [1, 2] proposes that teaching should aim into developing both creativity and rationality. Technology, science, social studies and arts are deeply connected. This relationship can clearly be identified in STEAM instructional approaches.

STEAM approach is considered a strong motivation for the learners involved and is related to better learning results, even in more technocratic fields, commonly known as "STEM disciplines", as described in [2, 3].

Future citizens need to familiarize themselves with change and learn how to react in different circumstances, in their personal and professional life. For this to be achieved, they need to learn how to combine different elements together and manage to adapt. STEM elements could be merged through art integration and provide a holistic learning experience [3].

Considering the educational reality nowadays, it is clearly assumed that the way science is being taught is not compatible with the students' and modern world's needs in any educational grade. Experimental and "try and error" procedures tend to be replaced by the "one and only" scientific truth, even if researchers and educators try to accomplish the opposite [4]. Creativity and personal contribution are excluded, as they are based on multiple perspectives and approaches [5].

International common cores tend to underline the significant role that creativity and problem-solving skills should hold in education today, due to the challenges future world proposes. Creativity and problem-solving are, in any case, the more mentioned and requested skills among the 21st century skills' framework [6]. So, in the years to come, stakeholders should invest on these skills along with STEM subjects, or just develop STEAM instructional frameworks [1].

According to further research, there is a prominent need to explore practical interdisciplinary implementations of STEAM methodology, so as to scaffold 21st century skills, such as problem-solving, scientific literacy and creativity [7].

This paper proposes an e-course, STEAMapT^{2}theGalaxy, designed by the principles of problem-based learning, purposing in a meaningful familiarization with the STEAM methodology, by its application in subjects that appeal to each one of the participants' interests.

1.2 The Purposes of the Research

The instructional design developed in this e-course and delivered through STEAMapT^{2}theGalaxy site, aims to:

- familiarize participants with STEAM methodology.
- help participants identify the educational potential of including STEAM approaches in their teaching practice and be able to apply them in real circumstances.
- develop problem-solving skills.
- enhance creative thinking.

2 Theoretical Framework

The e-course is based on the phases of "Creative Problem Solving" (CPS) model, proposed by Treffinger [8], which is combined to the thinking dispositions indicated by "The 6 Thinking Hats" learning and problem exploration strategy.

2.1 Problem-Based Learning Principles and the "Creative Problem Solving" Model

Problem-based learning refers to the teaching procedure that is based on real-life problems and problematic situations, which students explore within inter-disciplinary learning environments, usually working in groups, by the principles of active and collaborative learning [9].

The CPS model includes the initial problem solving steps, along with the parameter of inventing multiple innovative solutions in problems of gradual difficulty [8].

The steps of the CPS model are sorted in three larger dispositional groups, according to the attitude towards the "problem" that should be adopted in each one of them:

- Understanding the problem
- Generating ideas
- Planning for action

Each of the general groups named above, contains specific steps to be followed during the procedure. The activities included are executed in groups or individually, depending on the circumstances and the goals that have been set in the beginning of the process:

- Understanding the problem
  - Mess Finding (ph_1)
    In this step, the participant is informed about the subject of the e-course and tries to form an initial opinion towards it. That is the introductory problem-statement phase.
  - Data Finding (ph_2)
    Next, he is asked to collect information about the subject and clearly state the problem he is about to explore. Gathering data should be a careful and detailed process, as it is crucial for the steps to follow.
  - Problem Finding (ph_3)
    After information gathering and organizing, student is ready to clearly state the problem and decide the specific aspect of it that needs to be improved. Creative Problem Solving, either way, is about not only dealing with fully defined problems, but also figuring out ways to better manage a well-known situation.
- Generating ideas
  - Idea Finding (ph_4)
    Elaborative and flexible thinking is the key to this step, as it is important to come up with many ideas and possible solutions to the problem stated. The "one and only" solution is not accepted by the presenters of the model.

- Planning for action
  - Solution Finding (ph_4)
    As long as all the possible solutions are collected, selecting the one that best fits the given situation is feasible. This procedure includes ranking the options and identifying the advantages, disadvantages and the potential of each possible idea.
  - Acceptance Finding (ph_5)
    The final step is about planning the actual implementation of the solution chosen and predict all the assisters and resisters that may affect the whole attempt.

It is clearly stated that the steps numbered above can be used in the order that better facilitates the whole problem-solving process, without identifying wrong and right sequences.

2.2 "The 6 Thinking Hats" Strategy

"The 6 Thinking Hats" strategy [10] offers the framework for exploring the problematic situation stated in a creative and holistic way. Each one of the hats is related to a different thinking disposition, so as to cover all the aspects of the subject/problem discussed. Moreover, it has been chosen so as to present the steps that should be followed in an understandable and more descriptive way.

In contrast to the theoretical model, the strategy proposes a basic hat sequence depending on the circumstances under which is being used and the goals that have been set. For the "problem-solving" the most common sequence is the one that follows:

- Blue hat – controller of the whole process
- White hat – information about the subject
- Red hat – emotions and personal beliefs
- Black hat – possible dangers and obstacles
- Yellow hat – positive aspect and hope
- Green hat – creativity and possible solutions' generation
- (Blue hat – selecting the best solution and sums up the procedure).

2.3 Web-Based Educational Framework

As it has been mentioned before, the e-course was designed as an instructor-led and facilitated e-learning program that was delivered through an educational site hosted by Weebly. Building a site was the best option for the following reasons:

- The flexibility in design procedure [11].
- Instructor-led paths that could exceed the options given by a standard learning management system.
- Compatibility of multi-media tools.
- Wide variety of collaborative and scaffolding tools which could be embedded in the site.

3 Research Methodology

3.1 The Research Questions

The theories explained above were orchestrated properly in a web-based learning environment, called STEAMapT^{2}theGalaxy, in order to answer the research questions below:

- Can the workflow that is delivered through STEAMapT^{2}theGalaxy site be an effective instructional design by the principles of Creative Problem Solving in a STEAM course?
- What are the educational potential and affordances of STEAMapT^{2}theGalaxy which can contribute to the students' engagement and positively impact their learning outcomes?

In order to answer the questions above, a research methodology framework was designed.

3.2 The Instructional Design Framework

The phases of the "Creative Problem Solving" model where combined to the hats of the strategy explained above, creating a strong problem-solving framework. Participants had the chance to elaborate on a problem of their own choice, related to STEAM methodology, after they were introduced to the general concern about the STEM projects that are so popular in nowadays.

The phases were combined in order to better respond to the goals that have been set and the needs of the trainees' group. The "Idea Finding" and "Solution Finding" phases were grouped into one, on the grounds that in this way the creative process is fully approached and not disturbed. Furthermore, the "Problem Finding" phase was connected to three hats, as it is about defining the problem and predicting any clue that could affect its exploration (Fig. 1).

In each one of the steps, proper activities were included so as to help students reach the desired learning results. The activities in the first steps were individual, while in the middle the students worked in pairs and then in larger groups.

3.3 Key Performance Indicators and Assessment

Assessment was prominent in all phases, as an individual or group procedure. Individual assessment was included in every single phase as multiple choice questions, referring to the Key Performance Indicators (KPIs) that are examined in this educational scenario. The KPIs were grouped as follows:

- STEAM oriented
- e-learning system oriented
- creativity oriented

Moreover, students completed questionnaires about their prior knowledge (ph_0) and creative attitude (ph_4). In pairs, they assessed the lesson plans that had been

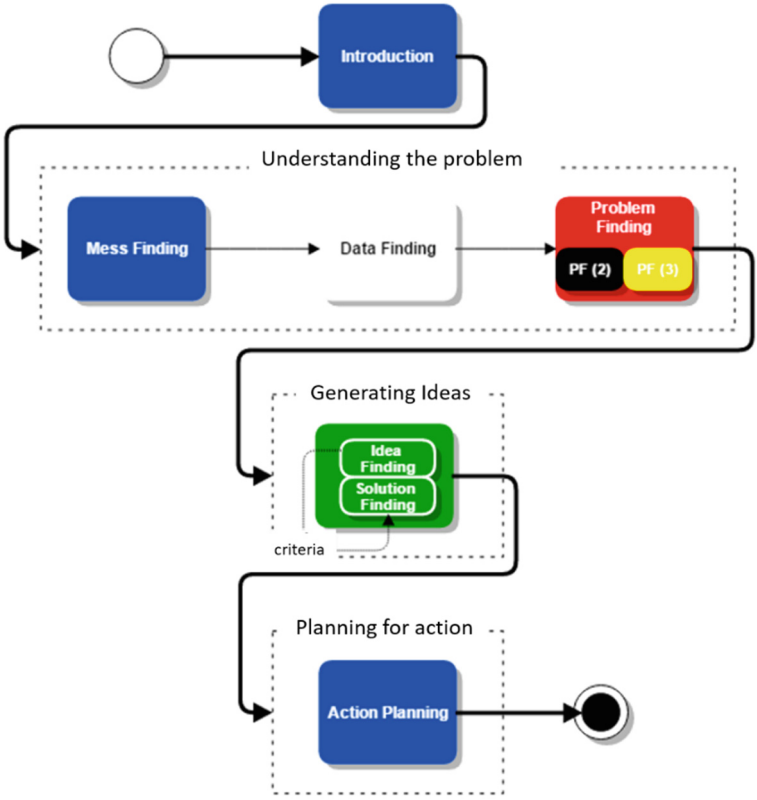

Fig. 1. The instructional design framework, by the principles of "Creative Problem Solving" and "The 6 Thinking Hats"

designed by their colleagues, in pairs as well, by providing detailed and constructive feedback. Ultimately, working individually, they assessed the course in general. In this way, assessment was an ongoing process so as to get specific and trustworthy results.

3.4 Tools Orchestration and Site Management

In the site, each phase of the educational scenario was presented in a separate page, while the navigation was linear. Any additional information and source was included as a hyperlink in "help" pages that were designed for every unit. In addition, communication forms enabled the communication loop between the instructor and the students and provided a strong basis for collaboration.

The case that was explored was delivered to the students as a story about traveling from the well-known STEM planet, to the unknown and full of secrets STEAM galaxy, after suspecting that the way STEM planet (projects, tools etc.) is being exploited today is not the proper one. Graphics were included in each page to correspond to this story, as well as make the browsing experience more understandable and fun. Finally, a blog

was designed on Weebly host, in order to enable students to share their opinions and express themselves. Blog posting is also necessary in several activities included in the e-course. Collaboration was supported by embedding Padlet, in problem stating phase (ph_3) and feedback providing process (ph_5) as it makes it easier to post, view and respond in each one's posts in real time. In both communication procedures described above, instructor was present to help and monitor students' interaction.

4 Findings and Discussion

4.1 STEAM Oriented Results

The first research question, which was about the instructional effectiveness of the workflow by the principles of Creative Problem Solving, delivered by the STEAMapT^{2}theGalaxy site, was answered by reviewing the students' responds in the rubrics that were related to STEAM methodology.

In the statistical analysis that was conducted, it was shown that the five aspects of STEAM methodology are supported equally and effectively with material and activities in the lesson plans that students design. Also, the students were able to conduct a careful research in terms of STEAM methodology and share their results, while they were successful in presenting and supporting methodology's advantages (new teaching practices, support different learning types, enhancing collaboration, enrich learning environment, include art in teaching etc.) by their work on them (Table 1).

Table 1. T-test analysis on the data collected towards STEAM basics supported in participants' lesson plans, that makes it possible to expand the conclusion to the relevant population

Test value = 4						
	t	df	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
					Lower	Upper
Exploration	8,507	84	.000	.506	.39	.62
Learning styles	7,447	84	.000	.459	.34	.58
Teaching approaches	10,101	84	.000	.612	.49	.73
Learning environment	11,581	84	.000	.659	.55	.77
Collaboration	8,091	84	.000	.518	.39	.64
Understanding	6,507	84	.000	.412	.29	.54
Arts	5,191	84	.000	.400	.25	.55

After implementing T-test analysis for these specific research individuals, it is possible to expand the results in the related population. Therefore, the e-course proposed in general, was proved to be suitable for familiarization with the STEAM methodology.

4.2 System Oriented Results

The second research question was related to the web-based system that was used to deliver the educational program. Specifically, it was about the educational potential of STEAMapT^{2}theGalaxy site, which could contribute to the students' engagement and the accomplishment of better learning results.

After the statistical analysis, it was clearly indicated that the educational web-based environment was suitable to the students' needs and managed to fulfill their expectations towards the supportive material provided, the interface quality and the communication paths that were included (Table 2).

Table 2. Correlation between the factors that are proved to define the success of the e-learning tool designed and used

	Supportive material	Ease of navigation	Communication with the instructor	Communication with colleagues
Supportive material	1			
Ease of navigation	.594**	1		
Communication with the instructor	.619**	.493**	1	
Communication with colleagues	.456**	.500**	.426**	1

**.Correlation is significant at the 0.01 level (2-tailed).

In the table presented above, it is proved that the variables examined are strongly connected. Therefore, it is important for all of them to be taken into serious consideration when designing e-learning programs. Students who had experience in e-learning, underlined the importance of these aspects as well, while agreeing (by 50%) that the ease of navigation is the one that matters the most.

5 Conclusion

STEAM is a promising teaching and learning methodology that could lead to better learning results for teachers and students and enhance their motivation to a high degree. E-learning is a proper area to develop such training and educational programs, as it is well related to 21st century skills and needs and it is compatible to STEAM methodology in general.

STEAMapT^{2}theGalaxy has proven to be a proper web-based approach for familiarizing with the methodology and experimenting in designing lessons according to it.

The way in which the framework presented in this article could be implemented in different learning environments or possibly be enriched by adding learning materials that could expand the subjects examined, remains to be seen.

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REFERENCES

1. Daugherty, M.K.: The prospect of an "A" in STEM education. J. STEM Educ.: Innov. Res. **14**(2), 10–15 (2013). http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1006879&site=ehost-live, http://ojs.jstem.org/index.php?journal=JSTEM&page=article&op=view&path[]=1744&path[]=1520
2. Williams, P.J.: STEM education: proceed with caution. Des. Technol. Educ.: Int. J. **16**(1), 26–35 (2009)
3. Henriksen, D.: Full STEAM ahead: creativity in excellent STEM teaching practices. STEAM J. **1**(2), 15 (2014). https://doi.org/10.5642/steam.20140102.15
4. Tytler, R., Osborne, J., Wiiliams, G., Tytler, K., Cripps Clark, J.: Opening up pathways: engagement in STEM across the primary-secondary school transition (2008)
5. Sternberg, R.J.: The nature of creativity. Creat. Res. J. **18**(1), 87–98 (2006). https://doi.org/10.1207/s15326934crj1801
6. The Partnership for 21st Century Learning. P21 Framework Definitions, pp. 1–9 (2015)
7. Ge, X., Ifenthaler, D., Spector, J.M.: Moving forward with STEAM education research. In: Emerging Technologies for STEAM Education, pp. 383–395 (2015). http://doi.org/10.1007/978-3-319-02573-5
8. Treffinger, D.J.: Creative problem solving: overview and educational implications. Educ. Psychol. Rev. **7**(3), 301–312 (1995)
9. Wood, J.C., Mack, L.G.: Problem-based learning and interdisciplinary instruction (2001)
10. de Bono, E.: Six Thinking Hats. Educ. Psychol. Pract. **4**(4), 208–215 (1989). https://doi.org/10.1080/0266736890040408
11. E-Learning for Teacher Training: From Design to Implementation Handbook for Practitioners. European Training Foundation, Italy (2009)