Assessment by skills of an interdisciplinary project in which mathematics is the common thread.

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In this contribution we propose the design of an interdisciplinary STEAM project named "Dark ages?". It is based on Project Based Learning (PBL) and outdoor learning, in which digital and manipulative tools, virtual and real experiences, in the classroom and in the real world, are intertwined. A formative and summative evaluation proposal is presented, and the first results analysed. Some results of a survey on how students experienced the project are also presented.

Keywords: Project based learning, outdoor learning, STEAM, formative and summative assessment, survey, secondary education.

1. Introduction and Theoretical framework

In many contexts it is stated that one of the tasks of the school is to "educate complexity", train and consolidate the skills of reading reality as a complex system, where many variables operate. Interdisciplinarity can be a way to provide the student with overviews of complexity, in which points of observation, languages and interpretations intersect. From this perspective an interdisciplinary STEAM project "Dark ages?" was proposed. The title itself "Dark ages?" is an example of an interpretation called into question by the question mark. Who says that the Middle Ages are a dark, backward, and difficult period in European history? When? For what reason? Is that true? The question mark raises a doubt, asks questions, broadens perspectives, goes beyond the cliché. The aim of the interdisciplinary project is to bring students to the heart of an era, the medieval one, through STEAM and other subjects, as literature, history and English literature. Part of the project took place at school and another directly in the places studied: Siena Cathedral with the Museum and The Piccolomini bookshop and Pisa with the "Scuola Normale Superiore", the tower of the clock palace where Count Ugolino had been locked up and the cemetery where the statue of Fibonacci is. The following methodologies are used in the activities: Debate, Active Learning, Outdoor Education, Peer Tutoring, PBL. Furthermore, online research activities and evaluation of digital sources and resources, laboratory activities related to the creation/sharing of materials in the Moodle institutional e-learning area and in other shared digital areas as Genial.ly for the digital Escape Room and Padlet.com, were used in an active learning perspective. The technological tools used were: GeoGebra, Desmos, 3D print, Fusion 360° software, Teodolite for on-site measurements.

The term STEM refers to teaching and learning in the fields of science, technology, engineering, and mathematics. STEM education aims to help the next generation of students to solve real-world problems by utilizing knowledge of multiple disciplines and horizontal competences such as critical thinking, collaboration, and creativity. The addition of the artistic skills to the science and technology education gave birth to a new acronym: STEAM (notice the addition of A for arts). Zemelman, Daniels, and Hyde (2005) provide insight into the ten best STEM pedagogical practices for successful integration of STEM disciplines. There are as follows; using manipulatives and hands-on learning; cooperative learning; discussion and inquiry; questioning and conjectures; (5) using the justification of thinking; writing for reflection and problem solving; using a problem-solving approach; integrating technology; teacher as a facilitator approach; using assessment as a part of instruction.

PBL has a lot of potential to enhance 21st century skills and engage students in real-world tasks (e.g., Kingston, 2018). It promotes interconnected worldview, links among disciplines, and presents an expanded view of subject matter (Blumenfeld et al., 1991; Kingston, 2018). Therefore, PBL is a promising teaching method for integrated science education that can be defined as an effort to organize or integrate science curriculum content into a meaningful whole by a constructive and context-based approach that crosses subject boundaries and links learning to real world (Czerniak & Johnson, 2014).

Learning outside the classroom essentially can be defined as use of resources out of the classroom to achieve the goals and objectives of learning (Knapp, 2010). The constant focus on textbooks and formal mathematical practice might invoke a view among students that mathematics is abstract, distanced and only useful in a in classroom context working only in the textbook. Existing research on outdoor learning in mathematics indicates positive affective outcomes and possible academic benefits from learning mathematics in an out-of-school context (Moffett, 2011). Moreover, outdoor environments, are real-life contexts enabling students to internalise, transfer and apply mathematical ideas and provides direct experience, and the students need to be active in the learning process. It lends itself to the Inquiry-based mathematics education a student-centred form of teaching whose guiding principle is that the students are supposed to work in ways like how professional mathematicians work (Artigue & Blomhøj, 2013). Lee et al. also suggested community partnerships, where students collaborate with professionals, as an important component of project based learning.

During the process of teaching and learning, teachers do assessment for learning (formative assessment) and assessment of learning (summative assessment). Black and Wiliam (2009) after considering the main features of teaching and learning defined formative assessment as: “Practice in a classroom is formative to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited” (see also Cusi et al. 2017 and Aldon et al. 2017). Inquiry based learning needs formative assesment due to it process character.

In this contribution we propose the design an interdisciplinary STEAM project such that students are actors of their own knowledge through collaboration and discovery. The research questions are the following: How can this type of activity be assessed? How do students perceive this type of activity and the way to evaluate it?

2. Methodology and participants

The project was addressed to two 11th grade classes, at Applied Sciences High School of in Udine, Italy. In this article only one class of 19 pupils will be examined. The methodology used for the formative assessment was that of continuous monitoring, with related feedback, of the Forums, Padlets, Logbooks, delivery of the results of the proposed exercises and control via the Moodle eLearning platform and evaluation of the oral presentation of the works. For the final skills for summative assessment, we proposed a rubric containing six macro areas summarized by the following disjoint descriptors: Collaborate, Evaluate, Read and Understand, Communicate, Digital skills, Learn. A survey was also proposed at the end of the project to evaluate the appreciation and the effectiveness of the proposed project. In addition to a descriptive statistical analysis of the closed questions, a thematic analysis of the open questions was carried out. In the future, a comparative analysis of the results obtained will be carried out.

3. The design of the Project and the formative assessment

Interdisciplinary STEAM project requires a completely different way of grading. The normal teaching activity is also remodelled and reorganized, alternating laboratory/experiential moments with moments of study/empowerment. A working methodology for "open classes" is adopted: in some lesson hours, the classes are merged and reorganized into groups based on the proposed activity. The underlying theme of the project was to analyse a historical era, the Middle Ages, from various aspects to answer the question: was it really a "dark age?" Among the various parts of the STEAM project, we will describe those where mathematics plays a predominant role.

Activity 1. "Fibonacci: the man who gave us numbers". The students discovered unusual or hidden aspects of medieval (and non-medieval) mathematics through the resolution of a digital Escape Room and shared among peers the mathematical properties discovered. Before this activity the students only knew the definition of sequences as particular functions defined on the set of natural numbers. They had already studied the Fibonacci sequence in the previous school year and this year, with the IT teacher, they reviewed it together with the recurrence sequences. Among others, in the digital Escape Room there were also puzzles related to real life contest. As formative assessment the students, divided into groups, had to discover the solutions to the questions asked, using all the resources they deemed useful. They had to note down through logbooks the solutions of the questions, with the strategy used, and the difficulties encountered. The results were shared with the other groups in the classroom during the lesson. The module on "Fibonacci" concluded with the creation of a physical Escape Room, revisiting of Dante's Inferno, which allowed other classes of the Institute to "taste" the medieval world. It was entirely designed by the students including the divisions of the rooms and the interdisciplinary puzzles to move from one room to another, included the costumes and sets just like real directors and actors. They used the Moodle Forum for sharing ideas.

Figure 1: Digital and physical escape room. The Fibonacci statue.

Activity 2. “The white cathedral of Siena”: a masterpiece of gothic architecture. Students, divided into groups, were asked to study the Cathedral of Siena from different point of view.

a) From a mathematical point of view: the students studied and (re)built some typical elements using the dynamic geometry software GeoGebra, such as friezes, rose windows, golden proportions, conics (see Figure 2 and 3). Individual student products were entered for evaluation in a Padlet.

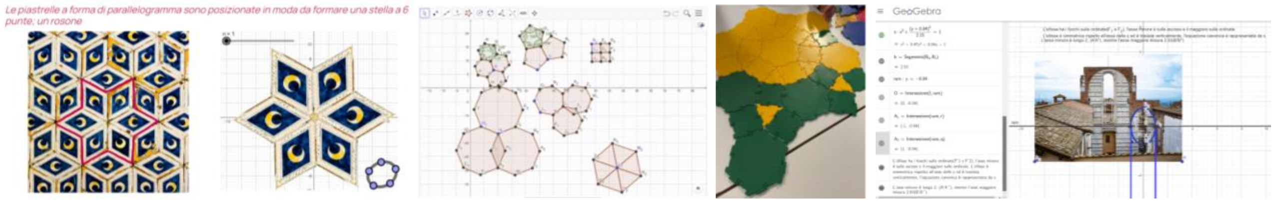

Figure 2: Tessellation of a detail of cathedral with GeoGebra and manipulative objects. Find conics.

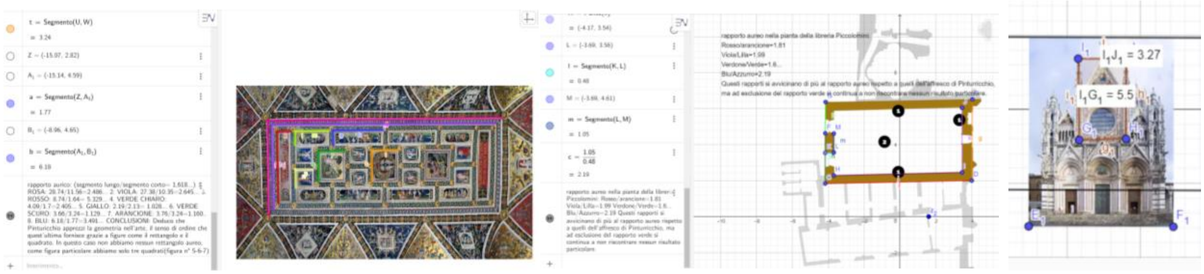

Figure 3: Let's search for the golden ratio!

b) From a historical-philosophical-architectural point of view, they studied the floor “Come stelle in terra” analysing the proposed allegorical meanings. In Figure 4 there are some examples.

Figure 4: Allegorical part

c) From Technology and Engineering point of view, with Peer tutoring, they tried to 3D print some elements by developing the Fusion 360° software and learned to use the Teodolite.

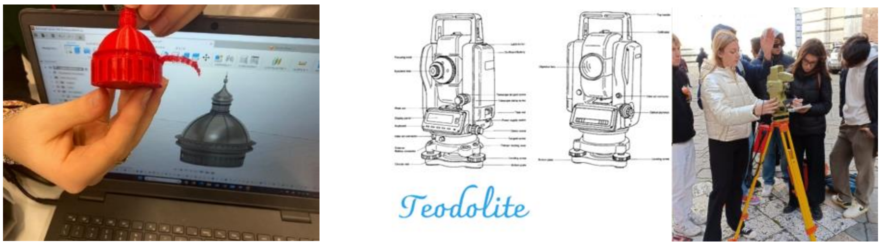

Figure 5: 3D print and Teodolite

As final activities of the project they also studied the Unity language to create a virtual museum, using 360-images. In figure 6 there are some examples.

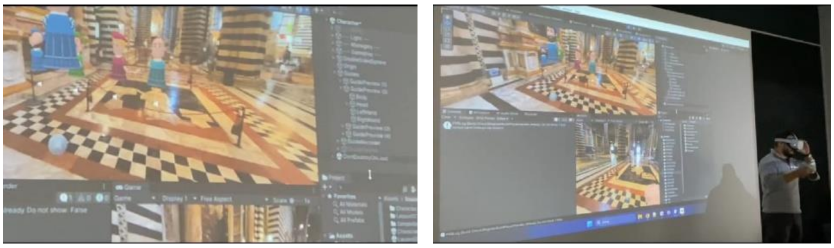

Figure 6: Multimedia production

3. The outdoor activity: The visit to Pisa and Siena. The visit included laboratories as: Physical measurements with the laser and with Teodolite, as an application of the trigonometry, using the plans provided to us directly by the Opera di Siena; mathematical and architectural studies with related data analysis; take photos, videos with the aim of preparing a virtual museum.

The students had the opportunity to delve deeper into the topics covered thanks to the interventions of experts: The architect De Benedetti of the of Opera for an architectural, geophysical, and historical-cultural point of view; Professor Bellissima, with a contribution of music to mathematics, who discussed Guido d'Arezzo and, starting from the miniatures contained in the Piccolomini Chapel which show the first forms of musical writing, he led the students to play with functions on the Cartesian plane which represent the various forms of musical writing from the beginning up to digital music; Professor Chiantini, who discussed “The fields of fortune”. He starts from a marble mosaic in the Cathedral of Siena, called “The wheel of fortune”, and proposed a reflection on medieval cosmology in the light of non-Euclidean geometries.

4. From formative to summative assessment

In relation to the final skills achieved by the students, we propose a rubric, inspired to The Periodic Table of Skills[1], divided into 6 macro areas: Collaborate, Evaluate, Read and understand, Communicate, Digital skills (Dig Comp 2.1), Learn. The group of teachers has chosen, under the guidance of the researcher, inspired to the periodic table (Table 1), to use for each macro competence, some items which are best suited to representing all the disciplines involved. Collaborate includes respect, group interaction, teamwork, valorisation of one's own and others' abilities, knowing how to manage conflicts. Evaluate includes respect shared criteria, to be able to reconstruct the operations carried out. Read and Understand include understanding the deliveries, recognizing the topic, recognize resolution and argumentative strategies, identify information that responds to one or more topics, relating implicit and explicit information, recognize the logical-syntactic function of an argument, critically interpret information. Communicate include, recognize the main theme or argument of a text or specific parts of it, capture the intentions and the author's point of view, correct the cultural references used to support the argument. Digital skills include manage data, information and digital content, share information through digital technologies, develop digital content, integrate and rework digital content, use digital technologies creatively. Learn include acquiring a specific working method by making mistakes, apply the main rules and formulas, plan and monitor learning, deal with problems by identifying the appropriate resources,

[1] https://www.curricolidigitali.it/il-progetto/341-la-tavola-periodica-delle-competenze21

identifying conceptual nodes and connecting them, evaluating information to support reasoned conclusions.

COLLABORATE					EVALUATE		READ AND UNDERSTAND						
Respect	Interact in a group	Teamwork	Enhancement of their own and others' abilities	Knowing how to manage conflicts	Respect criteria shared	AWARENESS: being able of reconstruction the operations performed	Comprehend deliveries	Recognize the theme the topic of an object	Recognize the strategies resolutions and argumentative	Individuate information who respond to one or more topics	Put in information report implicit and explicit	Recognize the function logical-syntactic of a topic	To interpret critically the information

TO COMMUNICATE			DIG COMP 2.1					LEARN					
FOCUS Recognize the theme or main argument of a text or specific parts of it	SCOPE Capture the author's intentions, point of view, or purpose	CONGRUENCE - REFERENCES Correctness and congruence of the cultural references used to support the argument	Manage data, information and digital content	Share information through digital technologies	Develop digital content	Integrate and rework digital contents	Use digital technologies creatively	Acquire a method specific to work doing errors	Apply the main rules and formulas	Plan e monitor your own learning	Dealing with problems identifying the adequate resources	Identify conceptual nodes and connect them	Evaluate information for hold up reasoned conclusions

Table 1: The Periodic Table of Skills

The need to have 2 votes on the register led us to unify some macro-sectors. In the first we merged Collaboration, profitable relationships, respect, civil discussion of ideas, management of other people's places and objects, theatrical interpretation and problem solving. The second included: interdisciplinary path, mathematical study, argumentative and expository ability (Table 2.)

Collaboration, profitable relationships, respect, civil discussion of ideas, management of other people's places and objects, theatrical interpretation and problem solving.																		
10	8,5	9,5	9,5	7,5	9	8,5	9	10	10	9,5	9	10	9	9	9	10	8,5	8,5

Interdisciplinary path, mathematical study, argumentative and expository ability																		
10 -	7	10	8	7	9	8	9-	8	8	10-	7	9	7	10	8	8	8	7

Table 2: Student results

As can be seen, the students' grades, from 0 to 10, were very high thanks to the interdisciplinarity of the project with a mean of 8 in the first case and 9 in the second. In 8 cases out of 19 the scores for the two types of judgment were close to each other (with a difference of 1 or 2 point). The scores of the first evaluation framework were far higher than the second in 10 cases over 19 while just in 1 case the second type of evaluation gave far better result. There is a positive correlation 0.41 between the two evaluations, meaning that the two ratings are not independent in the sense that the second is positively influenced by the first. But this correlation is not very high, which means that the two assessments managed to capture specific skills that would not have emerged with a single assessment.

5. The survey

A project evaluation survey was also proposed to the students. We report the results only regarding 4 over 36 questions: 1. Which aspect did you appreciate the most? 2. Which aspect bothered you the most? 3. I think that evaluating an interdisciplinary activity is adequate and correct. 4. How likely are you to recommend this activity to another class council at your school?

1. Which aspect did you appreciate the most? The appreciation of the group work and with the other classes and the visit to Siena were the most used. We report just some sentences in this direction: I appreciate the concrete observation of what was studied during the visit to Siena; Moments of discussion, brainstorming, research, and related sharing. The division of the material to be studied

between the classes and between the groups created in the classes. This allows us to delve into a specific topic in an exhaustive way without being totally unaware of the other aspects related to the macro topic; I appreciate the exchange of information between classes, especially when one class exposed something to the other class, the class listening could intervene by adding content or asking questions.

2. Which aspect bothered you the most? Most students did not find any negative aspects, Just for few the main problem is the time: required for the project seemed excessive for the fear of having to tackle the program too quickly, but not enough for visiting the cities.

3. I think that evaluating an interdisciplinary activity is adequate and correct. The possibility for the answers were: strongly disagree, disagree, neutral, agree and strongly agree. The 42% were strongly agree, the 26% were agree, the 32% were neutral and nobody disagree or strongly disagree.

4. How likely are you to recommend this activity to another class council at your school? On a scale from 0 to 10, only two gave a score of 4, the other was greater than 7 with a total mean of 8.

The project was appreciated, and this serves as an encouragement to design new ones.

5. Conclusions

The experience of an interdisciplinary activity where different student skills is brought into play is a challenge for both teachers and stimulating students. PBL involves a dynamic classroom approach, which emphasizes on long-term learning, interdisciplinary and student-centered activities. Students need both manipulative and technological objects and need to experience on-site activities. The possibility of interacting with teachers other than one's own and with experts is an opportunity to compare various communication and operational methods and offers opportunities for discussion, socialization, and integration between students. The activity also facilitates dialogue and collaboration between teachers, encouraging the sharing of effective strategies.

Students' assessment should be considered an integral part of instruction. Each instructional activity could be seen as an opportunity for the teacher to assess as well as for students to learn. Emphasis should be on formative assessment that aims at supporting students learning. This includes reflection, self and peer evaluation, and teachers' feedback throughout the project process. Assessment should include a specific end-of-project phase that ensures reflection on what was learned as well as the creation of a project artefact. A public presentation of the project supports students' communication skills, can motivate students, and presents an opportunity for feedback. Instead of a presentation, the product itself can be public.

We believe that A (for arts and design) in STEAM is an important addition from the original STEM approach. Arts and design permit a more divergent thinking in students, giving space to more creative solutions to problems. For a real implementation of STEAM, it is needed a radical change in the educational culture and administration. Curriculum and teacher assessment methods should change giving importance not only to the concepts but also the acquisition of transversal competences. Our findings highlight the importance of having an assessment rubric with criteria that addressed both disciplinary specific skills as well as generic STEM skills.

The excellent results obtained encourage us to promote other projects like this. But evaluating this type of project is not easy and it is a challenge that teachers are called upon to accept to have students who are increasingly ready to face the complexity of our times.

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