Embedding Digital Assessment in STEM Education: Lessons Learned from a European Joint Venture Focusing on Sustainable Development

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Abstract

Assessment of Transversal Skills in STEM (ATS STEM) is an innovative policy experimentation project, which aims to enhance digital assessment of students' transversal skills in STEM. This Erasmus+ project is situated in primary and secondary schools across eight European countries, involving 12 partners on different levels of educational system. Teachers and researchers have collaboratively developed and piloted several integrated STEM learning activities all focusing on UN sustainable development goals. Embedding formative digital assessment of STEM learners' work has been a central component. This paper provides an overview of the project and shares some results from Sweden and Ireland. We provide examples from practice that help illustrate the complexity with a particular focus on technology education.

Key Words: ATS STEM, Formative assessment, Technology Education, STEM education, Digital assessment, Sustainability

1. INTRODUCTION

Education has never been more important given the scale of challenges that we can face today; from pandemics to climate change and the massive global impacts of wars that are never just local. Technology is key to many of our efforts to address complex issues that arise from these concerns. Finding ways to teach technology in school has never been more important nor more challenging. Students require key transversal problem posing and solving skills that are developed from the logic of mathematics, the experimental rigor of science, and the solution orientated focus of engineering and technology. They also need competence in the digital (or analogue) technologies that enable the use of key skills in STEM environments. Technology is hence interwoven with STEM and its use in integrated STEM, where multiple disciplines are brought together to describe and solve problems or develop artifacts and ideas is a key challenge for educators.

1.1. Digital Assessment of Transversal Skills in STEM

Assessment of Transversal Skills in STEM is a project funded by Erasmus+ that was conducted in 88 schools from 7 different European countries (see www.atsstem.eu). The project sought to develop a rich and evidence-informed educational framework to improve educational outcomes for students with use of digital tools as central. A series of five reports were written after a desk-based research phase, to help provide a theoretical base from which the project could proceed (McLoughlin et al., 2020; Costello et al., 2020; Reynolds et al, 2020). Report #5 'Towards the ATS STEM Conceptual Framework' (Butler et al 2020) presented an integrated conceptual framework of standards for the assessment using digital tools. This became a conceptual tool to help us arrive at an understanding of what can be assessed using digital tools in schools. However, we also knew that this understanding was provisional and that the ultimate test of our learning design would be its translation into practice by teachers. Figure 1 below shows a high-level visual mapping of the framework and the expansion on the left side in the technology dimension which gave guidelines to teachers in selecting and using digital tools in their practice (Szendey et al 2020).

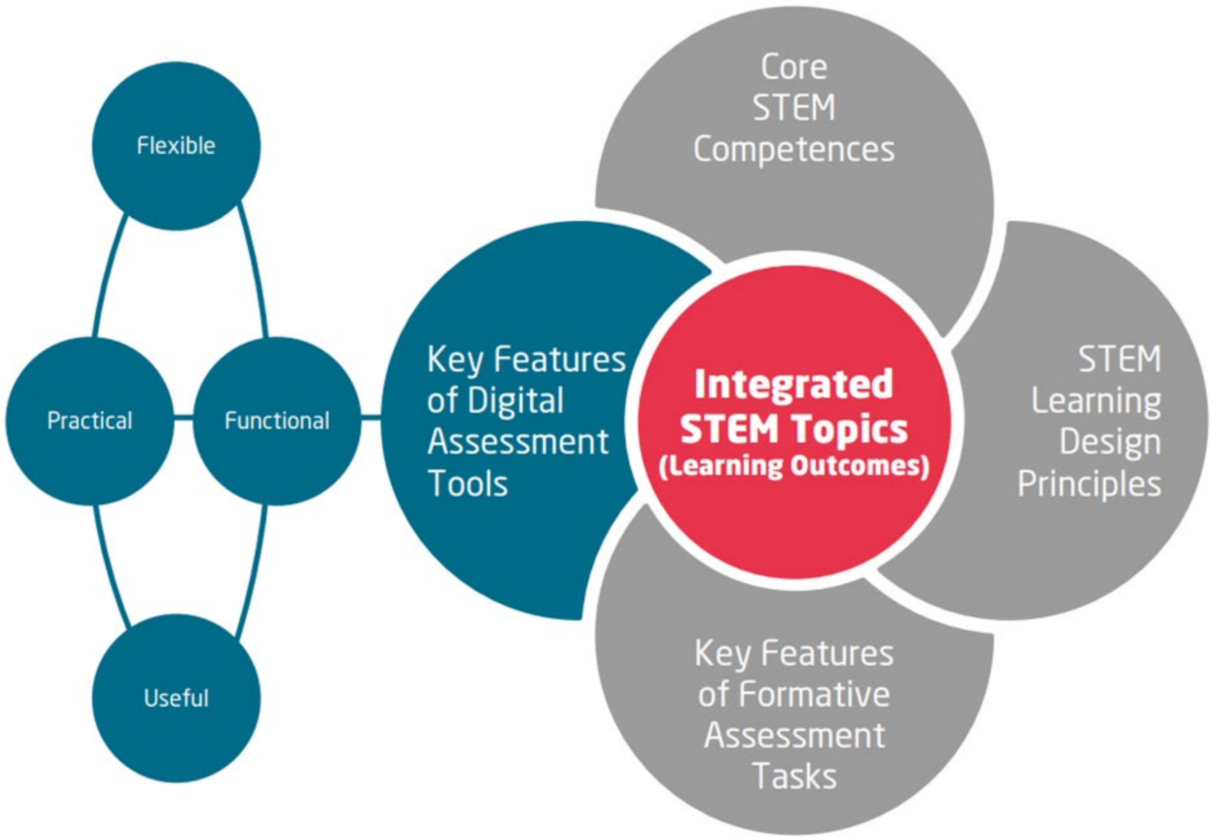

Figure 1: A high level visual mapping of the framework with the use of technology section (digital tools) highlighted

This framework was then used to help teachers design lesson plans that would allow them to teach students key skills and digitally assess those skills. In large part the lessons involved student use of digital tools, but also offline, outdoor, and unplugged approaches. This paper illustrates two examples of practices in Irish and Swedish schools involved in the pilot research and selected findings.

The examples were selected from many examples in the project because a common theme of the student work carried out in both countries was in developing their school environment (school yard and garden). There are commonalities in both examples but also differences. For example, in the Swedish context the system is moving from teacher-based assessment towards more high stakes terminal assessment in post-primary level. By contrast the reverse process is happening in Ireland and in the earlier years of the post-primary system the trend is towards more teacher assessed project work and less reliance on terminal examinations. These simple examples show the complexity of attempting to realize solutions that can scale in Europe and that implementations must be adaptable to contexts. Although there are challenges involved, we also attempt to illustrate via this paper how using technology in education can be powerful for student learning.

2. APPROACH AND CONTEXT

A comprehensive research program was developed by the project team (Fernández de la Iglesia et al 2020) to examine how the conceptual framework was used by teachers and its effectiveness in practice. In this paper we present case studies (Fig. 1) from Ireland and Sweden titled: "Sensory Garden" and "Open spaces". The projects were evaluated by gathering a variety of empirical data: teacher group interviews, student focus groups, mentor group interviews, classroom observations, and students' and teachers' artifacts following the ethical review committee approvals in each country. This included informed consent from parents, teachers, and assent from students.

The projects were piloted in Ireland during a level 5 lockdown and, as such, were impacted by COVID-19 restrictions. Schools did not reopen until from March 2020 to March 2021, and then on a phased basis. The intervention was carried out in two learning cycles, but no observations were carried out during learning cycle 1 due to the lockdown. In Sweden, the schools remained open for students and teachers, but no external people were allowed on site, hence the research team had to adapt their methodology to include online observations and interviews.

2.1. Why apply digital assessment?

The digital tools for assessment were infused in the educational projects as an integral aspect. We believe they must be deeply embedded in the design for learning to be useful for students and teachers. The motivation to apply digital assessment might be high, however the skills to do so may be challenging. Teachers and teacher mentors drew on teaching tools they were familiar with but used the project to deepen an expand their use in creative ways e.g., investigating peer assessment with comparative judgment and using digital platforms like Microsoft Teams and Book Creator for self and peer assessment.

2.2. What are the challenges to using digital assessment strategies?

One identified challenge in the project was that the process of assessment is not always explicit, and the teachers did not talk much about assessment, even when prompted about it during the interviews. For example, the use of quizzes to check if a student had grasped the content provided during lesson was not considered as assessment per se. We believe this is a result of the teachers having incorporated formative assessment as an integral part of their teaching and could be worth studying in the future.

3. ILLUSTRATIVE EXAMPLES OF STEM ACTIVITIES

Interpretation and implementation of Technology and Engineering in practice varies across all eight project partner countries. Preparing students with critical skills for the 21st century is a complex challenge, one in which technology education must occupy greater space and play a larger role in schools to allow every student the opportunity to flourish. Developing structured support and guidelines is key, and in the ATS STEM project the use of digital tools was embedded in all aspects of the project and students used a variety of digital tool concepts such as design from engineering. Within the scope of this paper, we have chosen two examples (of many) to illustrate what the theoretical framework might look like in practice with a particular focus on technology education.

3.1. Ireland Case Study: Sensory Garden

In Ireland, students completed two learning cycles. The first learning cycle was concerned with students designing a 2D Sensory Garden and an arch. A Sensory Garden was planned to be designed and built in the school during the summer of 2021. This task allowed students to contribute their ideas before the landscape designer and builder implemented the project. 19 students from a final year class were involved in this project led by 1 primary school teacher. The subjects involved in this project were Mathematics, Science, Art, and History. The class produced 2D design plans of the garden, plans of an arch for the garden followed by self-assessment of the design and a Mentimeter quiz.

The context for designing a 2D garden was the UN Sustainable Development Goal 3: Good Health and Wellbeing. This goal integrated the following topics from the Irish curriculum: 'A sense of space', 'Using pictures, maps and models', 'Human environments' and 'Natural/built environmental features and people'. The task of designing the sensory garden focused on two core technological competences: Problem-solving and Innovation and Creativity.

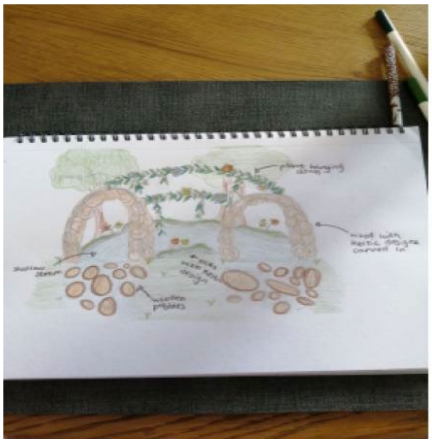

Figure 2: 2D plans for Sensory Garden submitted on Padlet

The elements of innovation and creativity that they engaged in were using their imagination, coming up with new ideas, and physically creating something original. Both the learning outcomes and success criteria were defined and shared explicitly at multiple stages with students via digital tools. By the end of the activity students were expected to be able to formulate research ideas for a sensory garden, measure the area of the garden, and design a 2D map of the garden. The success criteria were identified as students being able to identify at least three items for the sensory garden and produce a 2D draft plan to scale with the location of sensory items labelled. Students used tablets to take photos of their work and digital tools such as Blooket and mentimeter to give each other feedback on their designs. Feedback in interviews and focus groups particularly highlighted that participants valued the elements of peer assessment that were enabled by digital technologies.

Figure 3: Student measuring in sensory garden.

3.2. Sweden case study Open spaces

The multi-disciplinary STEM project Open Spaces involves digital peer assessment of authentic real-life problems where 10–12-year-olds redesigned an open public space from an UN Agenda 2030 perspective with a particular focus on design, choice of materials, and transportation. This multidisciplinary project included the following subjects from the Swedish national curriculum. Mathematics, Chemistry, Technology, Biology, Physics, Arts, English and Swedish as well as Swedish as a second language. Students completed two learning cycles where the first one had a more theoretical approach, where they e.g., learned about technical drawings, including measurements, and comparing them to the physical environment [the open space]. They also learned about properties of different building materials and how to choose different materials based on their properties as well as transportations, from a sustainable perspective. The second cycle had a practical approach where they e.g., built a 3D model of their idea and comparing them to the physical environment in the open space using digital tools. Figure. 4a shows a student group comparing their theoretical sketch with the outdoor environment. Figure 4b shows the model built by the students, and excerpt from student portfolio where they motivate their choice of material and why they chose to build a jump yard with trampolines and a large swing, thus remake their open space in the way they wanted. "*We chose trampolines because we think it would be fun for children. We chose a large swing so that many people can fit and swing together."*

Figure 4a and 4b. Left: Students comparing their sketches of their suggested redesign of the open space on site. Right: The sketch, model inserted in the open space and excerpt from portfolio.

The students worked in groups of three or four and peer assessed each other's work via Adaptive Comparative Judgment (ACJ) in a digital cloud-based environment (RM Compare)– facilitating several schools to be involved. This allowed students to view and provide feedback to a potentially larger, more varied set of examples than traditional face-to-face peer feedback – resulting in lasting noticeable differences in capability among learners. Thus, even though CJ has limitations (particularly technical and cost implications), there is significant potential to support learning that should be investigated further, concurrent with Hartell and Buckley (2021). Relying on the judges' (students) making pairwise comparisons of stimuli (digital portfolios) each student was asked to individually provide peer feedback in writing on the groups work. These comments were then compiled/assembled by the project management and fed back to the students' groups. The group portfolios, prior and after peer review, were analyzed in combination with the feedback comments.

4. DISCUSSION AND CONCLUSION

Digital tools may be widely used in classroom activities, but we must ask whether these are intentional deliberate practices, embedded in the reflective teaching work or something teachers do in a more routine manner. In this case teachers were offered to reflect and more deliberately use digital tools in support of student learning via the ATS STEM project. Here, teachers were supported in different ways e.g., design learning activities, workshops etc. The teachers who committed to be observed during classroom practices said they were supported by that too. Also, the teachers were clearly highly motivated by the projects. They described how they could incorporate real world skills and interdisciplinarity in their teaching in enriching ways. They came across as real enthusiasts and working with the lesson planning elements of the project clearly fuelled their spirit and passion for improving their teaching. In future projects, it is important to spread this energy and enthusiasm among other students, teachers, and organizations.

During this project we have seen examples of where digital assessment tools have been used to facilitate feedback, e.g., the peer feedback activity in *Open spaces* using comparative judgment (CJ) software. Future projects should consider focusing not only on the benefits for learners but also the challenges involved for teachers to plan and set up the activities. The limited number of devices at some of the piloting schools were very challenging; we recommend that future projects assess the technical infrastructure as a baseline and build on existing resources.

There are also structural hindrances that do not support the implementations of digital tools in teachers and students' assessment practices to support the development of transversal skills. The digital tools that have been included in the case study may have supported the students' progress. We want to believe that, and we base our beliefs primarily from the results derived from the interviews where students' motivation is expressed along with and gratitude for doing the projects and stating that they would like to do them all over again next year. Other structural hindrances may be the challenges for teachers to work collaboratively - this is not unique to the pandemic. However, within the Swedish education system there are many teachers who collaborate with themselves in interdisciplinary projects as they teach many subjects.

The results showed that the students enjoyed doing the projects and their motivation clearly increased. How this increase in motivation affected their learning needs to be investigated further. However, results show they now know about Agenda 2030 and have expanded their vocabulary as well as their digital toolbox. Analysis of the feedback comments may conclude that the quality of the feedback could be improved - from a theoretical point of view. However, the interviews show that the students appreciated the feedback they received, especially through comparative assessment process, but also that they need to be trained for the process. It is thus difficult to interpret what the students learned from this feedback process, but the results undoubtedly show that the students enjoyed the process and evidence from the student work also shows that they used the response received from the feedback process to improve their work, which is what matters the most regarding feedback.

The overall enthusiasm and engagement among students and teachers in this project are difficult to convey in text. The students taking part in the project have increased their digital assessment competence and literacy, they now know the words for critical thinking, collaboration, communication, global goals, and Agenda 2030. Using multiple digital tools, they learned first-hand how to frame and then tackle broad issues of sustainability.

This project has contributed to provide opportunities for collaboration and support from outside the schools as well. The project has raised student (and teacher) awareness around global issues. Even though they may not fully understand these issues, they now know of them, which is one step in the right direction. In combination with the global movement among young people and how the students in the case study schools express a wish for doing similar projects in the future, their foundations have been well laid.

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