JOURNAL OF E-LEARNING AND KNOWLEDGE SOCIETY
Vol. 17, No. 3 (2021), pp. 33-42

INVITED PAPER

Creative Learning in STEM: towards the design of an approach between theory and reflective practice

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(published: 31/12/2021)

Abstract

The paper presents and discusses the Research and Development and related reflective practice process for the design of an approach to STEM school education. It focuses on Future Inventors, an education project of the National Museum of Science and Technology Leonardo da Vinci which aims to design, develop, test, and define an approach for teaching and learning in STEM at junior high school. Through this case study, the authors argue for the need to design for learning activities in which children can learn creatively building on their own potential and, for educators, to develop and maintain a STEM teaching mind-set that recognizes a series of qualities, bodily engagement, emotions, self-expression and open-ended, creative exploration, as having a legitimate place in the science classroom This is an attempt to move beyond the de-contextualised use of technology in learning towards a learning flow that fosters engagement with digital experiences a way to develop children's thinking, their voice and identity, making them feel able to share and contribute actively.

KEYWORDS: STEM, Learning, Aesthetics, Approach, School, Digital.

DOI
https://doi.org/10.20368/1971-8829/1135559

CITE AS
Xanthoudaki, M.,& Blanton, A. (2021). Creative learning in STEM: towards the design of an approach between theory and reflective practice. *Journal of e-Learning and Knowledge Society*, *17*(3), 33-42.
https://doi.org/10.20368/1971-8829/1135559

1. Introduction

School STEM Education has been the object of innumerous studies, debates and attempts for many years and internationally, most of which strongly claim the need to innovate both approach and tools for teaching and learning. This, not only for schools to be able to remain at the pace of times (i.e. integrating technology in classroom practice) but, more than that, for the need to create a context in which children can learn creatively building on their own potential (Resnick, 2017). Self-expression, creativity, agency emerge as ever more important in the learners' own experience while educators are invited to develop and maintain a STEM teaching mind-set that recognizes a broad range of experiences, skills and behaviours as having a legitimate place in the science classroom. It is an effort towards "broadening what counts", that is, towards creating a supportive and inclusive environment in which all students feel that they can contribute from their own lived experiences and that these are valid and valued (Harris et al., 2018). Enriching STEM teaching and learning at school also means redefining learning as

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such, seeing it as a process of "being, knowing, becoming" (Petrich et al., 2013, p. 53) in which "the cognitive act becomes a creative act which involves the assumption of responsibility as well as autonomy, an act of freedom" (Rinaldi, 2006, p. 141).

But how do we design an approach that contributes to this overarching goal that is authentic, inspiring and transferable? How can we know we contributed something new? The paper tries to answer these questions through the examination of the learning design process for 'Future Inventors' (FI), an education project of the National Museum of Science and Technology Leonardo da Vinci developed between 2019 and 2022 with the support of Fondazione Rocca. The project aspires to contribute a (new) teaching and learning approach for STEM education in junior high school. To meet the project goal, a team of educators built on an extended Research & Development process, which gradually evolved into reflective practice. The paper examines this experience arguing for the value of integrating pedagogical research with reflective practice as a tool for designing learning opportunities that give children a chance to be creative and self-expressive with STEM.

Reflective practice or, otherwise, "living ourselves in a permanent state of research" (Rinaldi, 2006, p. 137) is seen as a requisite for pedagogical innovation and professional development through which practitioners engage with their own experiences, learn to appreciate, to be aware and to understand experience itself (Eisner, 1985; 1998). In this sense, the process of reflecting on practice is regarded as equally important as the process of designing practice. For these reasons, the discussion of the Future Inventors approach, still in development, is done through the discussion of the reflective practice experience as it was encountered by the project team, aiming to: 1) contribute insights regarding learning spaces and experiences that build on a dialogue between material and immaterial, physical and virtual as tools for teaching and learning in STEM; 2) emphasize the importance for practitioners to be important (equal?) actors in the research activity along with scholars and researchers, contributing to broadening what counts as learning (Bevan, 2017).

2. Future Inventors: the project as a context for research

The project emerged from the need to contribute towards the enrichment of STEM education at school, today still characterized by transmissive approaches and rigid teaching structures (Biondi, 2020); the need to support teachers in acquainting themselves with new (digital) tools, often closer to the agendas of their own students than to their own ones; and the need to reinforce the stance that sees children as active constructors of knowledge (Papert, 1980).

To do this, the project uses the Future Inventors lab, a new learning space at the Museum dedicated to Image and Sound, chosen because they are, at the same time, STEM curriculum topics and digital expression means widely used by young people (Manjoo, 2018). The lab is the context of research and includes a range of learning activities, from immersive experiences using art installations to inquiry-based experimentations that encourage interdisciplinary, creative and active explorations of contents. The digital and the analogic, the physical and the virtual, the material and the immaterial blend into the same learning flow mixing tools and means of expression (Raffone, 2018). Digital culture is exploited to engage learners promptly in an experience which can be deep and articulated and activates new connections and understandings (Xanthoudaki, 2018). Our intention is to move beyond the de-contextualised use of technology or its use through a pedagogy that remains the same as before. Instead, we use this opportunity to extend learners' creative thinking in STEM through an approach that fosters engagement with digital experiences contributing thus to develop their thinking, their voice and identity, making them feel able to share and contribute actively (Sawyer, 2006; Escueta et al., 2017; Resnick, 2017, 2018; Papert, 1980).

The lab, resources and activities were designed by the Museum education staff in collaboration with several experts and are also the context for the pilot testing of the FI approach in collaboration with schools, in two parts: the first one involved 12 expert teachers with the aim to co-design and reflect on the characteristics of the approach and its transferability into the school practice; then, a series of collaborative professional development experiences with teachers and learning experiences for students aim to test and refine the approach. It is worth mentioning that for both co-design and pilot testing phases we asked for the participation of science, technology, and art or music teachers. This was intended to promote interdisciplinarity through the collaboration among teachers of different disciplines, something not common at junior high school level.

Our intention to involve the teachers as co-designers was in order to give them agency in both the process and the product that is Future Inventors, for several reasons: the first is that teachers have intimate knowledge of context and practice, as well as relationships with the students, that we do not. This is significant because we are designing activities that are opportunities for creative self-expression. Because each student is unique, they require enough freedom to orient their projects around their interests to meaningfully connect with their curiosity. Since we will not be in a direct relationship with the students for most of the time, we cannot maintain the relationship of curiosity, openness and respect for their ideas that is the best means of supporting their creative process. Only the teachers, by virtue of their proximity, can do that.

We can, however, try to establish a relationship with the teachers that is similar to the kind of relationship we hope they will create with their students during the project - one of acceptance, curiosity, and most of all respect. That is not possible without granting them agency, and indeed responsibility, in reinterpreting our design and intentions in their classroom. Such reinterpretations from the teachers are also one of the best ways we have of getting feedback to improve our program in both the short and long term.

The paper discusses the project from its beginning and up to the conclusion of the co-design process with the expert teachers. It draws attention to the theoretical principles that influenced our thinking, the explorations of ideas in practice, the factors that changed the course of the design and the feedback from the expert teachers regarding methodological choices and transferability to school practice.

3. Developing Our Approach: Blending Theory with Personal Repertoires of Practice

When the Museum team accepted the challenge of FI we knew that this was not an easy task: the education field, both formal and informal, is full of wonderful projects and innovative resources that try to change traditional schooling. The Museum itself has been the protagonist of several of those so we knew that change is slow, and that defining anything new and capable of making a difference would be the very last phase of a long process. But the challenge resonated perfectly with our mission. The Museum has been dedicated to learning since its foundation in 1953 and investing in educational research since 2009 (Xanthoudaki, 2013). This time we had to take a step further: not (merely) design resources for teachers and students, but use the project as a context for research to come up with an approach to learning that helps question fossilized attitudes and bring change; not (at all) do yet another project in coding or a series of isolated 'tech-in-education' experiences for students, but create a 'learning flow' that looks into learning as a value, "creating a synthesis of the individual and her context, in an affective relationship between those who learn and that which is being learned" (Rinaldi, 2006, p. 141). But, even more, FI presented an opportunity to look into our practice with its idiosyncratic nature, history and identity within a process of reflection that would bring an understanding of how we can contribute to the transformation of STEM learning in the long run. The work acquired thus an action research dimension in the sense of a self-reflective, research-oriented inquiry to enhance direct practice and improve the rationality and justice of our practices, our understanding of these practices and the situations in which the practices are carried out (Carr & Kemmis, 1986). It meant a rigorous examination of which pedagogical elements from our own approach we should use to reinforce STEM learning and which ones we needed to question as a way to introduce change. Action research, in the form of conversations among the team of educators, was dedicated to observing and problematizing through practice, "thinking for themselves and making their own choices, asking themselves what they should do and accepting the consequences of their own actions" (Smith, 2017). As Bevan & Xanthoudaki, 2008, p. 108) argue, we wanted to:

> *"explore the theoretical basis for alternative conceptions of knowledge and learning and discuss how they can [...] address deep-seated instructionism conceptualizations that may currently operate to limit the reach and impact of our work, namely:*
> *1. subject matter conceived as an array of discrete concepts and facts (as opposed to a set of cultural and social practices);*
> *2. learning conceived as moving knowledge from "out there in the world" to "in here in the head," (as opposed to the development of increasingly sophisticated, autonomous, and active practices);*
> *3. learners conceived as universalized beings (as opposed to subjective agents with dynamic funds of knowledge and repertoires of practice)".*

To do this, we chose to maintain some of the methodological principles that we knew worked well in our work, i.e. the combination of content, approach, materials, environment and facilitation in the design of our learning spaces (labs); the tinkerer's disposition, strong in our Tinkering activities, that state of mind of taking oneself through a process of exploring a problem rather than solving it (Petrich et al., 2013; Bevan et al., 2015); our approach to professional development based on the notion of the teacher as learner and reflective practitioner (Tickle et al., 1999; Xanthoudaki, 2007); and, of course, inquiry-based (science) learning, constructivism, constructionism and project-based learning, a well-established, solid basis to strengthen the idea of knowledge as experience through the creation of a "conversation with the material" (Schön, 1983 in Resnick & Rosenbaum, 2013, p. 165) and the construction of artefacts as a way of understanding and learning (Vossoughi & Bevan, 2014).

But the goal of coming up with a new approach for STEM learning meant that we also needed to break the ground and introduce methodological elements and concrete ideas for practice that were new and original. The direction we wanted to take was towards a "STEM learning ecology" according to which the learner constructs her personal STEM ecosystem and STEM identity through a range of educational experiences; and it is this 'identity' that gives a sense of ownership when it comes to engaging in STEM-oriented experiences. It means that we, as educators, needed to "build on what young people bring to the learning experience – their interests, skills, and personal areas of expertise – and help youth see how their interests can extend into the future" (Bevan, 2016).

In FI we acknowledged the fundamental importance of creative thinking as well as the plurality, complexity, thus the richness of learning which is continuously influenced by personal stories and interactions with stimuli from the world around us. Personal stories and interactions with the world are not only pedagogical tools to exploit, and foster, with learners but have also been a decisive factor in our learning design process. The components of the FI approach were influenced by the pedagogical debate and case studies from ours and other fields or professional practice, but were also shaped by some particularly inspirational moments that "made us see" - aha! - a solution for what we were seeking, and thus take a decisive turn in the development of ideas (Irvine, 2015). We mention two of those:

The Ars Electronica Festival 2018 – one of the pivotal events for understanding the potential of the digital for blending a range of fields into rich experiences – was the opportunity to encounter artists that "converse" with, and integrate the STEM fields into their work. Among those, Gerhard Funk and his Cooperative Aesthetics (www.youtube.com/watch?v=AxBfStEbwi0) represented a powerful inspiration for the conception of some of the fundamental components of the FI approach. Funk's research and work focus on the creation of immersive spaces in which participants can live collective audio-visual experiences and in which bodily engagement, immediate feedback, collaboration and the negotiation of behaviors become fundamental components of what takes place. Cooperative Aesthetics, now part of the FI lab, offered the opportunity to explore the notion of immersivity and embodied cognition and their role in learning, and represented the first important stimulus to the team to design experiences around the theme of (digital and analogic) Image. The paper takes Cooperative Aesthetics as a case study to discuss our process of design for learning in FI.

Following that, the visit of the team to the "CALDER-PICASSO" exhibition at the Musée Picasso (www.museepicassoparis.fr/en/calder-picasso) helped us reflect on, to later introduce, the notion of aesthetic experience. While in the exhibition, and in the following discussions, we realized once more the ever-lasting dialogue between art and STEM. The theme of the Void, or the absence of space, was explored with curiosity and intellectual challenge by Calder and Picasso; for us it represented a beautiful example of the power of art in (re)interpreting a STEM-related concept stimulating at the same time emotions, an appreciation of beauty, connections and new meanings, all of them qualities of the aesthetic experience (Knobler, 1967). How would it be, we wondered, if we tried to create a similar dialogue within a teaching/learning situation?

What was increasingly brought to the surface of our thinking were a series of qualities acknowledged for their role within an individual's experience but unfortunately still not considered equally valuable in STEM learning: bodily engagement, emotions, self-expression and open-ended, creative exploration (Girod, 2007; Claxton, 2015; Chemi et al., 2017), all of which can be also seen as constitutive elements of the aesthetic experience (Vecchi, 2010).

Aesthetic experience is an overarching notion with great pedagogical potential. In our case it encompasses all the qualities we want to introduce into FI and, defined as follows, determines the nature of the learning activities and experience designed for the project:

- a way to interpret human experience, which a) recognizes our body as the means to encounter and understand the world around us, the body perceived as the unity of senses, gestures and words; recognizing thus the importance of the physical experience as learning tool; b) is guided by curiosity and awe and inspired by beauty to create new meanings; c) inviting the creation of connections, at both cognitive and affective level, among ideas, objects and experiences (Vecchi, 2010; Girod & Wong, 2002; Dewey, 1934/1980; Girod, 2007; Claxton, 2015; Xanthoudaki, 1997).
- a pedagogical tool, compelling, transformative and unifying, through which emotion and anticipation become the flywheel for change and for the desire to pursue similar experiences; and which mixes the value of creating knowledge with the value of exploration, joy and the expression of ideas, thoughts and emotions (Dewey, 1934/1980; Girod & Wong, 2002).

4. Why Should Aesthetics and Subjectivity Matter in STEM Learning?

Many resources for STEM education, including ed-tech software and toys, are "closed-ended", that is, designed to help children solve problems that have one correct answer. If there is any exploration involved, it is designed to lead the learner down one or two firmly beaten paths. Such approaches to learning seem based on the assumption that school is where you learn all the things that are already known. Only after you have learned the already known you can start to do new things and explore new possibilities.

Patrick Fleming, professor of mathematics at South Dakota School of Mines and Technology, once told [Amos Blanton] that he felt he was never given the opportunity to be creative with math until just before entering graduate school (Fleming, 2008). All his years of math in primary and secondary school and most of his time as an undergraduate at university were more or less devoted to memorizing the things other creative people had figured out. It is possible that in order to be creative with mathematics, one has to first absorb past work for a few decades, as though it were an immense alphabet one is forbidden to doodle with before it can be recited perfectly. This is an idea that Papert, a mathematician himself, fervently disagreed with and worked to change

(Papert, 1993), but which arguably still dominates education today.

If we want people to learn to be creative, we need to invite them to practice creativity and to develop a creative mindset. One approach to doing this involves creating the conditions for ‘bricolage.’ Bricolage was first described in the literature by Levi-Strauss in his book “The Savage Mind” (1966) as a primitive kind of thinking, contrasted with formal, rational reasoning: "The basic tenets of bricolage as a methodology for intellectual activity are: Use what you've got, improvise, make do" (Papert, 1993, p.144). While Levi-Strauss made a clear distinction between the formal methods of scientists and the ad-hoc methods of the bricoleur, Bruno LaTour showed that much of the work of science, even today, involves bricolage (in Papert, 1993, p.150), and we would argue that the same is true in the fields of design and engineering.

Any creative act of synthesis involving technology – from designing a new toaster to coding an app – requires bricolage of existing components. Achieving quality requires a process of iterative reflection to explore different designs and configurations. We often think of design as a way to make a product, but it is also a process of building an understanding. This must be practiced to be learned. Pedagogies of creative learning like constructionism often invite the learner to make projects in order to engage them with the process of gathering context, proposing, iterating, reflecting, and testing. These processes, when engaged in with authentic interest and motivation, constitute most of the educational value of the experience. Because unlike a specific project or outcome, learning a mindset or design process is highly portable. It can be applied to many different contexts and conditions in the future, even in futures we cannot predict or imagine.

But if learners are to practice and develop their skills at iterative reflection and bricolage, some requirements must be met. One is that they must be given the chance to work on open-ended problems. Closed-ended problems with a single right answer - which we might call optimization problems - do not invite the same kind of inventive creativity that open-ended ones do. Giving children only closed-ended problems to solve is like giving them the freedom to do exactly what you tell them to do. It doesn’t allow for the exercise of subjectivity, the bricolage of concepts and ideas that are meaningful or interesting to them. It doesn’t give them the chance to learn how to make use of their own freedom and sense of aesthetics.

One challenge with open-ended problems is knowing where to begin, and how to explore a problem space. This is an area where the learner’s subjectivity and aesthetics become important. An open-ended problem - like designing a building or a piece of software - can have many different successful solutions, what Mardell et al. (2021) referred to as “More than one way.” The process of creating one’s own solution is subjective. It involves the creation of self-imposed constraints and sub-problems within which creative solutions must be found. If you love brick and hate concrete, you have a constraint to begin to explore and propose designs for your new building. The learner’s own subjectivity, interests, and sense of aesthetics constitute the foundational elements of their curiosity, motivation, and inspiration. These in turn guide and shape the choices the learner makes in the process, becoming their means of navigating, step-by-step, the near-infinite possibilities of open-ended problems to arrive at a meaningful (and actual) destination. In our view, subjectivity and aesthetics are indispensable to the creative process not only in the arts, but also in STEM.

5. Capture – Focus – Engage: A Possible Methodological Framework

One of the most important ideas adopted in the process of designing the FI approach was that of the ‘learning flow’; instead of a series of stand-alone activities, we foster a single and gradually evolving experience which invites learners to explore, and engage with, STEM-oriented situations, differently from one passage to the next, thus scaffolding their knowledge and skills and building a deeper and more meaningful relationship with STEM.

Our initial thinking was inspired by the ‘attention-value model’ of Bitgood (2010) meant for museum exhibitions to examine and improve visitor attention. It suggests three levels of attention - capture, focus and engage - each distinguished by qualitative and quantitative types of attention and by the combination of psychological and physiological processes at work. The levels represent a progression from broad, unfocused attention to narrow, deep processing of exhibit information.

Although referring to a different context, what we liked in this model was the frame it offered for developing our learning flow to integrate consolidated and new methodological elements into a progressive learning experience. We imagined the learning flow as going from *capturing* attention through a response to a powerful stimulus (Bitgood, 2010, p. 5); to *focusing* on a single aspect as a way to elaborate and deepen into concepts (p. 6); to *engaging* through deep sensory-perceptual, mental and affective involvement and a personal interpretation that would lead to meaning making and a deep, emotional response (p. 10).

This frame allows us to place, beside inquiry-based science and project-based learning, what we view as potentially pedagogically powerful methodological elements: Art (as process and product), creativity, aesthetics, immersivity, bodily engagement – in the form of arts installations, activities, tools, and materials – within a learning flow and a space, our Future Inventors lab.

In the lab, Capture-Focus-Engage was transfered in the FI lab as follows.

Capture experiences build on digital art installations which explore STEM-oriented concepts. No explicit reference is made to STEM, while encounters are of immersive nature and characterized by an interaction with immediate impact at emotional and aesthetic levels. Immersion and aesthetic experience help engage the senses, cognition, emotions, the body, often in unexpected ways and offer a series of meanings and insights that stimulate reflection among the learners.

In Focus experiences, STEM contents and digital tools, which lie at the basis of the installations, become the subject of experimentation that helps learners encounter and explore the science concepts and the technologies, understand their qualities and how they might connect, and build basic knowledge to enable reuse of learned concepts in other situations.

In Engage, learners build on the knowledge, skills and experience developed in the previous phases to conceive and design their own project with a strong self-expression and storytelling dimension.

As we sketched out potential activities for each phase, we began to investigate the question of what might constitute a 'high quality' project by a student at the end of the Engage phase. We decided that a successful Engage project should be unique and reflect the learners' synthesis of the concepts and ideas they encountered in the Capture and Focus activities. This is a high bar. But it is also an opportunity for the child to exercise their capacity to do bricolage, an experience that we feel is pedagogically valuable.

It follows then that in designing experiences to prepare learners to do bricolage, we would need to think carefully about the various interfaces between the tools and concepts encountered during the Focus experiences, in order to leave them prepared to use these ideas and tools as building blocks for their final project.

Our theory became the object of a learning design process that contributed the necessary empirical experience that would, hopefully, lead to defining the approach. Capture, Focus, Engage became key terms for our own discussions, explorations and documentation, conceived in an inter-relation and as the *fil rouge* connecting everything that takes place in the lab. They became the 'containers' for continuously bringing in and evaluating ideas, tools, as well as potential collaborators to test our theory and understand the rationality and justice of our practices. Collective conversations were full of analyses of our experience and reflections on the phenomena before us, helping to develop a new understanding of the constitutive characteristics of the emerging Future Inventors approach.

A key moment of this process was when Amos Blanton joined the Museum team as an external advisor, a role which soon evolved into one of co-designer and 'discussant' of our ideas and choices. The now extended team worked together and shared important moments of reflective conversation up until the co-design phase with the expert teachers. What follows is the discussion of the process of design for learning that took place during that period, a fundamental phase for both the purposes of the project and our own professional development.

6. Designing a Focus Activity for Exploratory Learning: 'The Cave'

At the beginning of the design residency in January 2020 we considered how the conceptual structure of Capture-Focus-Engage could be reinterpreted as a framework for gradually removing constraints to offer greater creative freedom in an open-ended activity. Capture experiences are relatively constrained, in that they invite the child into an experience which, while playful and expressive, cannot be "hacked" or radically redesigned. Focus activities invite them to a deeper exploration of the elements and tools used to make experiences like the capture activity, and permit modifications or "hacking" of existing tools and materials. The Engage phase, the least constrained, invites them to make a project representing a new synthesis, based on their own unique interests, knowledge and the creative confidence developed in the previous phases.

Represented graphically, the progression from limited possibilities in the Capture phase to the more open-ended Engage phase resembles a funnel. Travelling upwards from the bottom or spout, the widening walls of the funnel represent the gradually opening constraints of the activities, enabling exploration of a wider and wider space of possibilities. As the learner gains more experience and confidence, their ability to make use of their freedom and the creative potential within the activity increases. In this way the structure of the activity resembles the arc of human development and individuation, but on a smaller time scale.

This funnel structure as mapped onto Capture-Focus-Engage solves several problems. On the one hand it avoids the effect of giving a creative learner too much freedom too soon, often referred to as the 'blank piece of paper' syndrome. When offering a child of 8-12 years a blank piece of paper with only the prompt to "do whatever you like," many will not know where to begin. The experienced designer of open-ended learning activities will instead offer a more constrained prompt to help get them started encountering the possibilities of the tools and technologies involved, and then broaden the realm of possibilities as the activity progresses and the children's confidence grows.

Based on this framework, we began to imagine how children might 'hack' Gerhard Funk's Cooperative Aesthetics (conceived as a Capture experience) as part of a first Focus activity. Using laptops, projectors, software and materials commonly available in schools, we built a platform for children to develop activities that roughly mirror the kind of interactive and expressive possibilities of Cooperative Aesthetics. From this came a draft description of a Focus activity we called "The Cave," which the children would be invited to explore after experiencing Cooperative Aesthetics.

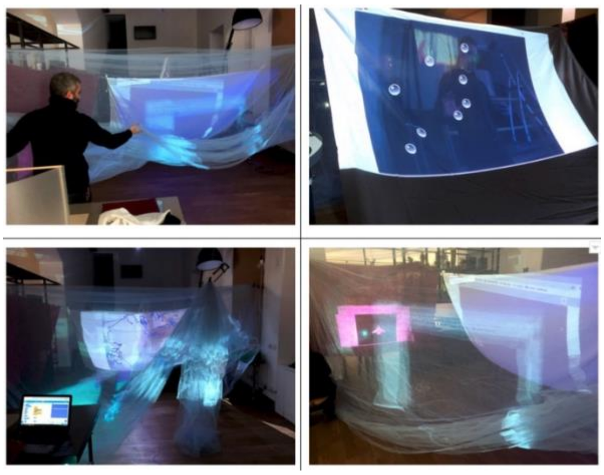

Figure 1 - Different potential configurations for the Cave activity.

In the activity, children are invited to experiment with interactive projection using the video sensing capabilities of Scratch, free software developed at MIT and used by millions of children around the world.

Scratch makes it possible to interact with projections using physical movements recognized by the laptop's camera. [Shown in this video: https://vimeo.com/604017159]. The "Cave" activity emerged from our own exploratory and playful experiences as designers, which we hope will be a rich and fertile ground for children's ideas.

Out of this process of imagining a first Focus activity and subsequent group reflections, several important design principles emerged. First, focus activities must have a "low floor" (Resnick, 2017) – a long established constructionist design principle meaning that the tool or activity is "user friendly" and easy to get started with. Secondly, a Focus experience should have a link to the general aesthetics, behavior, and user experience patterns defined by the Capture experience. Our goal is to spark deeper aesthetic and creative exploration within those domains – in this case interactive projections triggered by physical movement. While Cooperative Aesthetics uses laser tracking to sense bodily movement and drive the interactivity, the Cave uses Scratch's video sensing capability for a similar purpose.

This iterative design process of building with what's at hand, trying it out, and then reflecting and refining ideas and products is very similar to the process described by Resnick (2017) in the creative learning spiral and by Schön (1983) in his description of reflective practice.

7. Co-designing with Teachers

These ideas were put to the attention of the 12 expert teachers. Our intention was to share the whole R&D process with the objective to integrate their perspective into our 'prototype.'

Proof of the potential of our ideas for school practice was received in the form of appreciation from the teachers, but what was even more inspiring was our discussions and shared reinterpretations of the key concepts. Teachers considered Capture-Focus-Engage, aesthetic experience and other qualities (interdisciplinarity, bodily engagement, digital culture, etc.) for what they can do if brought directly into school.

Their considerations, following, substantially enriched our work and what will become the object of the following testing phase:

The FI approach could foster inclusive learning in STEM as it offers the opportunity to students to use subject-knowledge across different fields together with a range of "*linguaggi*" to build situated learning experiences that engage them cognitively as well as emotionally – but this *only* if the learning flow can be addressed as a unique, evolving process [The literate translation of "linguaggi" is languages. In the education field, the term has been widely used by Reggio Children to indicate the many ways children use to express themselves in addition to the spoken language. In this paper, we use the term to mean to the expressive, cognitive and communicative languages together with the many art-oriented expressive and interpretative means. www.reggiochildren.it/assets/Uploads/Rechild-24x34-MALAGUZZI-ESEC-taglio-low.p1.pdf].

Capture was truly inspiring and positively challenging for the teachers. They saw a potential for a strong impact for students' learning in STEM, but only under the condition that its unique qualities – the poetic and 'theatrical' nature, the physical and sensory engagement, the artistic aspect and the potential of triggering questions and new explorations – can be reproduced in the school context in a similar way as they are in the Museum.

Engage was seen as the open-ended conclusion of the learning flow, totally influenced by the learners' own direction and choices, their knowledge, skills and previous experiences, both pre-acquired and those built through Capture and Focus. Although project-based learning is not new at school, Engage represents a way to interpret and express STEM-oriented ideas through a personal journey of creative exploration. In Engage, digital and analogic tools, *linguaggi*, encounters with art and all the experiences in Capture and Focus are mixed with the learners' personal context into a narrative that is meaningful to the learner. As is true for Capture, transferability of Engage at school can be of impact and benefit only if we can guarantee the possibility for open-ended explorations and authentic self-expression for the students, that can lead to realizing their own stories and ideas.

Finally, we discussed the opportunity to address the learning flow not as a linear process (one phase brings to the next) but as a circular one in which Engage, and the students' own project work can become the starting point for a new Capture, thus a new learning flow for them or for other students.

For all this to happen, though, we need a strong basis, that is:

- the commitment of the school organisation to take up the necessary changes (from learning spaces, to resources, to scheduling of the work), starting from the headteacher and down to teachers working together across disciplines.
- the possibility for teachers to be directly engaged as learners in similar situations allowing for personal experience and self-reflection before any attempt to bring this approach to their students.
- a new conception of the resources necessary; not (anymore) a collection of technologies and related protocols to implement in class and 'be done with' once and for all, but an open-ended combination of: methodological reflections, materials and tools that are not fixed but are chosen by the teachers (and students?) on the basis of the direction they want to take, examples to enrich their insight, and ways in which students can document their own learning experience.

8. Conclusions

Each child brings her own unique experience, knowledge and interests to any learning situation. To acknowledge this is to recognize the depth and complexity of teaching as a dialog that can be prepared for, but never scripted. But it is possible to create a structure out of activities that the learner, in collaboration with the teachers, can reshape to feed their curiosity within the immense and fascinating realm of science. Any pedagogical approach that accepts that each child is unique, and not an object but a subject in their own right, must help educators establish a dynamic balance between structure and freedom.

In the process of designing FI, we explored ways to establish such balance by creating a dialogue between STEM and artistic expression that involved aesthetics and allowed for broad expressive possibilities. We did this using the same tinkering approach that we will invite the children to learn through. In working with the teachers, we showed them the same respect and deference to their expertise and situated knowledge that we will ask them to give to the children.

A lot of questions remain to be answered in the direction we chose to take. For example, how does aesthetic experience work in these learning experiences - and why? Is it about (and does it suggest) relationships, as Bateson (1979) pointed out? Is it a kind of glue that invites bricolage-ing certain ideas? Or is it more true to say it generates a kind of reverence for things that makes possible an open mindset where curiosity is free to roam?

These questions will be explored in the coming phase working with local schools and also be the subject of a empirical research in collaboration with King's College London that will help define the FI approach and investigate the ways it can affect STEM teaching and learning at school.

There is still a lot of work to be done. This project is not like a blueprint, where success is judged by adherence to a predetermined plan. It is more like a trellis on which we hope things will grow. Success can only be proven in time, over many iterations, by the flowering of a culture of creativity and exploration in the museum and the classroom.

Acknowledgements

The authors are part of the education team of Future Inventors. Maria Xanthoudaki is the project leader and Amos Blanton the main external advisor to the project. The team also includes Fabrizio Stavola and Stefano Buratti, Education Curators, Patrizia Cerutty, Head of Science Education Programmes, and Matteo Villa, Learning Research Officer, all staff of the Museum. They have all been valuable components of the reflective practice process and important contributors to everything that is discussed here.

We would also like to thank the expert teachers Mara Balasso, Lisa Baldella, Annalisa Catalano, Angela Bolis, Alessandra Bertola, Daniela Berardino, Roberto Agostini, Leo Izzo, Sara Cannoni, Lorenzo Caponetti, Maria Grazia Pistono, Marco Rabino for their enthusiastic contribution to the project.

The co-design phase took place in Spring 2021 while the testing with local schools, as well as the research of KCL, began in July 2021 and will be concluded in the summer 2022. The results of this study will be available by the end of 2022.

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