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## A Spider's Approach To STEAM

### Abstract

In this paper we present an overview of different approaches towards STEAM education, including the choices in methodology and pedagogy. From these various viewpoints we build up a framework for STEAM education and relate it to a real-world problem, namely, how a small spider can catch a prey.

### Keywords

Dewey, transdisciplinarity, 21st century skills

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### Various approaches to STEAM education

It is commonly advocated that one of the goals of the educational system is to teach future workers how to function in a highly technical, ever changing environment. So-called 21st century skills, like problem-solving ability, communication skills and critical and creative thinking are considered to be essential for successful participants in our society. In line with this movement, STEM education emerged within the scientific disciplines. The STEM acronym stands for the disciplines Science, Technology, Engineering and Mathematics. It is nowadays recognized and widely used as an over-arching discipline that connects the various content topics and incorporates the above-mentioned 21<sup>st</sup> century skills. While educationalists consider STEM to be a better means for preparing students for the future society than the classical separate disciplines, policy makers and captains of industry use STEM as a vehicle to promote scientifically-oriented careers from an early age on (Caprille, Palmén, Sanz, & Dente, 2015) (Committee on STEM education, 2011). Nowadays STEM is common in the formal and informal learning processes in most countries, with even elementary and secondary schools designating themselves as STEM schools. All of this is based on various frameworks of what STEM actually means. Based on these frameworks a vast literature is being compiled of the successes and pitfalls of STEM education. In recent years STEM has suffered various critiques. It remains difficult to obtain a full integration of the various disciplines partly because the nature of disciplines differ fundamentally, disciplines like science and technology are over-represented with often few attention on mathematics and engineering, by focusing on STEM other important disciplines are neglected. Therefore a re-conceptualization of STEM is needed in order to be able to reach the above-mentioned goals.

One possible re-conceptualization of STEM is STEAM, where the 'A' stands for the arts. This idea is not new and can be traced back to great universalists like Da Vinci:

*Principles for the development of a complete mind: Study the science of art.  
Study the art of science. Develop you senses – especially learn how to see.  
Realize that everything connects to everything else.*

Using this idea in the education process and considering the child as the central object, Dewey (1902) criticized the use of separate disciplines as means of studying the world:

*The child's life is an integral, a total one. He passes quickly and readily from one topic to another, as from one spot to another, but is not conscious of transition or break. There is no conscious isolation, hardly conscious distinction. The things that occupy him are held together by the unity of the personal and social interests which his life carries along. Whatever is uppermost in his mind constitutes to him, for the time being, the whole*

*universe. That universe is fluid and fluent; its contents dissolve and re-form with amazing rapidity. But, after all, it's the child's own world. It has the unity and completeness of his own life. He goes to school, and various studies divide and fractionize the world for him. Geography selects, it abstracts and analyzes one set of facts, and from one particular point of view. Arithmetic is another division, grammar another department, and so on indefinitely.*

(Dewey, 1902)

In recent times, STEAM was incorporated into the national curriculum in Korea in 2009 (Korean Ministry of Education, 2009). In the Western world John Maeda, former president of the Rhode Island School of Design, was one of the recent advocates, claiming that innovation happens when convergent and divergent thinkers join forces, translating this into STEM + Art (Maeda, 2013). But what does STEAM actually mean and how can it be used into the educational process? Due to its apparent novelty and disparate emergence, various frameworks for STEAM education are being promoted.

A first point of discussion is the interpretation of the 'A' in STEAM. A narrow view interprets 'A' as the visual and performing arts. It has been argued that these latter offer a means for conceptualizing, understanding and expressing science and that '*they cultivate a particular kind of ontology, a complex combination of being lost in the moment and utterly present, an experience that lies at the heart of inquiry-based science education*' (Gershon & Ben-Horin, 2014). The special role how the arts introduce creativity, both in the inquiry process as in the final presentation of the results, has further been highlighted (Guyotte K. , Sochacka, Constantino, Walther, & Kellam, 2014) (Guyotte K. , Sochacka, Constantino, Kellam, & Walther, 2015). On the other hand, taking more the holistic point of view of Dewey, 'A' is considered by others as meaning the liberal arts and humanities. Kim (2016) extends STEM with arts, history, geography and bibliography. Others, like Quigly, Herro and Jamil (2017) include the liberal arts, like English language arts and social studies. An even broader re-conceptualization was given by Krug and Shaw (2016) by introducing the concept of ST®EAMS, which includes besides the arts and humanities, also sustainability education (S) and interdisciplinarity and curriculum integration (®). In the remaining of the text, we will use this latter view and consider STEAM to be an integrated approach between the disciplines of science, technology, engineering, arts, mathematics, the humanities and ecological awareness.

What kind of topics are to be studied within STEAM? Most authors state that open-ended, real-world problems are to be considered as they most likely offer the best possibilities for a true integration of the various disciplines. Using real-world problems raises the motivation of the learners when they are related to their everyday-live experiences or offer the perspective of a meaningful solution of a valuable problem (Kim, 2016). On the level of integration between the various disciplines, various approaches are being used. At the lowest level we consider what can be denoted as STEM+Art. Here, one starts from the classical STEM approach (integrated disciplines or not) and adds an art component. This component is often reflected in an artistic presentation of the results, e.g. a dance performance or video presentation at the end of the project. At best this approach can be deemed multidisciplinary since various disciplines are involved, although no interaction between the disciplines is present during the project (Kim, 2016). In an interdisciplinary approach ideas from different disciplines are brought together to understand and solve the problem (Quigley, Herro, &

Jamil, 2017). Although this approach goes beyond the multidisciplinary view, its findings still remain within the disciplines. On a higher level acts the transdisciplinary teaching method, which focuses on the content of one discipline and uses contexts of other disciplines, to make the context more rich. While this method is preferred, it is not always attainable (Quigley, Herro, & Jamil, 2017). A serious point of caution when selecting the problems is the level of difficulty. It is a tendency in educational circles that learning should be interesting and fun.

*Human nature being what it is, however, it tends to seek its motivation in the agreeable rather than in the disagreeable, in direct pleasure rather than in alternative pain. And so has come up the modern theory and practice of the “interesting”, in the false sense of that term. The material is still left; so far as its own characteristics are concerned, just material externally selected and formulated. It is still just so much geography and arithmetic and grammar study; not so much potentiality of child-experience with regard to language, earth, and numbered and measured reality. Hence the difficulty of bringing the mind to bear upon it; hence its repulsiveness; the tendency for attention to wander; for other acts and images to crowd in and expel the lesson. The legitimate way out is to transform the material; to psychologize it – that is, once more, to take it and to develop it within the range and scope of the child’s life. But it is easier and simpler to leave it as it is, and then by trick of method to arouse interest, to make it interesting; to cover it with sugar-coating; to conceal its barrenness by immediate and unrelated material; and finally, as it were, to get the child to swallow and digest the unpalatable morsel while he is enjoying tasting something quite different. (Dewey, 1902)*

It is within the human nature to seek the path of least resistance. That which holds for mathematics obviously holds for other disciplines also, or to paraphrase Euclid, *There is no royal road to STEAM.*

STEAM is presented almost exclusively in the form of problems to the learners. The discipline is problem-centered which means that subject-matter content and attitudes are learned through the solution of real-world problems. This already includes a radical choice in pedagogy. Although some critique has been uttered on the choice of these pedagogies (see e.g. (Kirschner, Sweller, & Clark, 2006)), various forms of problem-centered education are nowadays promoted. Kim (2016) uses the performing problem method because of the hands-on approach. In this method the advisory teacher participates actively in the project as the project manager, the relation thus being more a student-teacher dyad instead of student-centered as in e.g. problem-based learning. Quigley, Herro and Jamil (2017) (see also e.g. (Herro & Quigley, 2017)) promote the use of problem-based learning, with problems where there are multiple solutions (see e.g. (Hmelo-Silver, 2004), (Savery, 2006)).

As noted in the introduction, STEAM is considered to be an excellent vehicle to introduce the 21st century skills in education. Because artwork is more about questioning and understanding concepts than finding answers to a given problem, it is in essence inquiry-based and as such is analogous with principles of critical thinking (Ghanbari, 2015). Based on a collaboration between students in art education, engineering and landscape architecture, Guyotte e.a. (2014, 2015) conceptualize STEAM as a social practice of doing that reflects concerns for community engagement and ecological sustainability. Building on the reflections

of the participating undergraduate and graduate students, they derived three domains within the social practice. Thinking through materials helps for a better understanding of real-world, ill-structured problems, while considering the audience is essential to effectively communicate the message and empathizing with others is an integral part of the design process. Finally, engaging with the community opens up the way to the public's preferred modes of communication. As such the collaborative potential embedded in STEAM education is immense.

### A spider's web framework for STEAM education

A spiderweb is a spider's STEAM solution of a real-world problem. In order for a small spider to catch a prey it constructs an artistic and scientific masterpiece. It involves technology and science in the kind of threads and the way they are used, mathematics is reflected in the symmetry and shapes involved, art and engineering in the way each particular

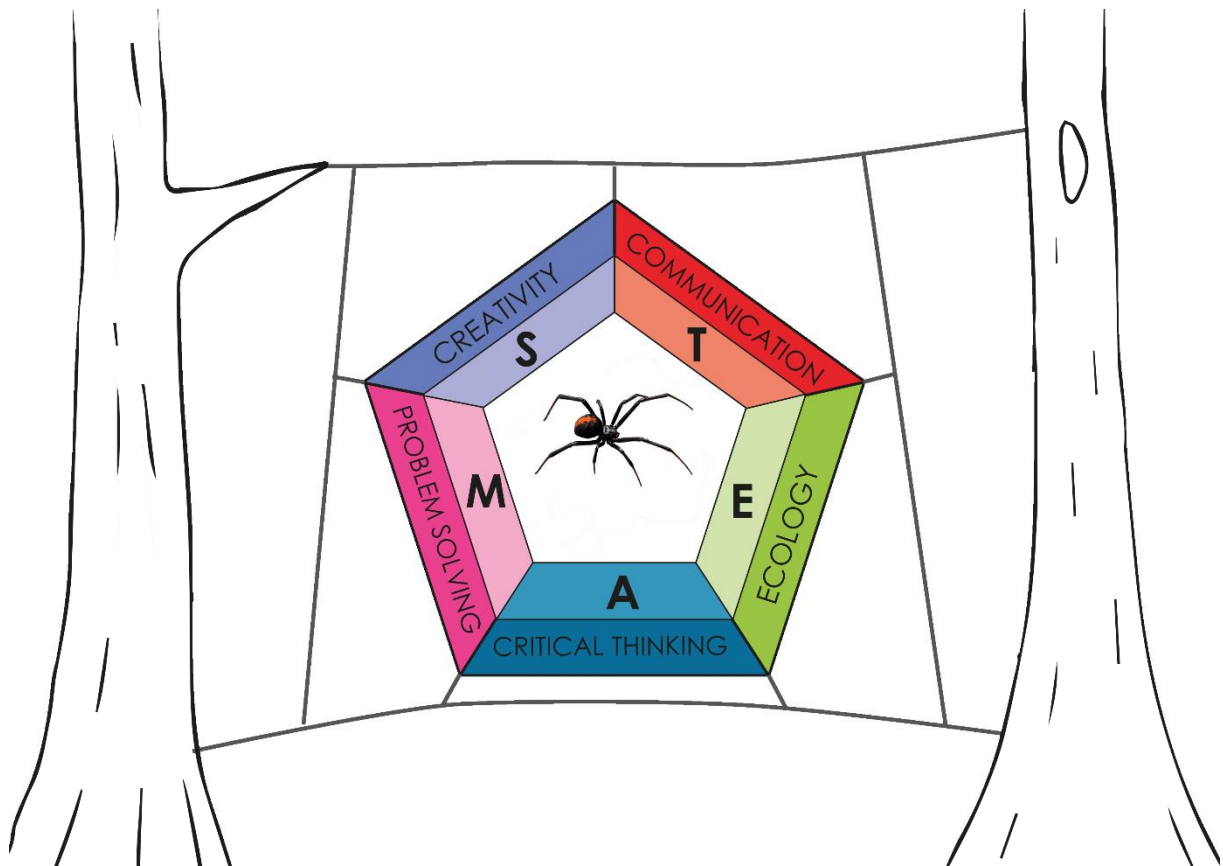


Figure 1 A spider's web framework for STEAM education.

web is adapted to its surrounding.

Building on the above-mentioned points, we conceptualize STEAM as a transdisciplinary interaction between science, technology, engineering, mathematics, arts, humanities and ecological awareness. The content is delivered in a performing problem method, where students and teachers co-operate as co-researchers. It is the role of the teacher to select those problems that arouse interest by the students, meet the set goals of the educational process and are within reach of the capabilities of the learners. In this sense the problem is the center of the spiderweb out of which everything starts. The goals are always dual in nature. A first ring

around the center constitutes of the content in the various disciplines. A second ring emphasizes specific attitudes and skills, like e.g. critical thinking, communication skills and creativity. These rings are connected with a multitude of threads, all linkages between content and attitude and skills. The threads represent the performing problem method. The web is attached to the world through strong treads which represent the teacher. It is the teacher who makes the difference in the learning process, who in the background regulates the process through successful selection of the problems, feedback and feed forward during the problem finding and solving process and careful and adequate evaluation afterwards (Hattie, 2012). And where is the student? The student is the spider in the web, starting from the problem and moving back and forth between the disciplines, attitudes and skills, but always safeguarded by the teacher.

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