A Conceptual Framework for Computational STEAM Integration. Crosscutting Concepts, Threshold Concepts, Border Objects and their propagation in STEM integrational fusion

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This proposal introduces the theoretical framework of Computational STEAM integration as well as its conceptualization for instructional practices, with a view to developing a conceptual framework for the epistemology of Computational STEAM. The purpose of this article is: (i) to summarize the state of the art for the different approaches of STEAM epistemology and integration, (ii) to go beyond and suggest some directions for future research, and (iii) to propose the inclusion of the Computational Science methodology in STEAM epistemology, mainly by provision of boundary objects. The role of Computational Thinking practices and the computational artefacts as boundary objects is extensively presented together with the role of threshold concepts.

Key words: STEAM, Epistemology, Integrated STEAM, Computational Science, Computational Pedagogy

Introduction

The problems that humanity meets need a holistic approach that cannot be faced by "isolated" disciplines or by stereotype methodologies based on traditional cognitive areas (National Academy of Engineering, 2016; Bryan & Guzey, 2016). There is also a general consensus that the purpose of education is not about teaching separate disciplines, but the focus of teaching should be on to "develop a reliable compass and the navigation tools to find their own way in a world that is increasingly complex, volatile and uncertain." (Schleicher, 2019, The OECD Learning Compass 20https://www.oecd.org/education/2030-project/teaching-and-learning/learning/30).
The fourth industrial revolution (Industry 4.0) is based on the integration of Technology with the Natural Sciences, the Health Sciences and the Engineering (Deloitte Access Economics, 2014) as well as the so called "STEM competences".

STEM and STEAM is also related to the established 17 Sustainable Development Goals (SDGs) presented in The United Nations' 2030 Agenda for Sustainable Development (Boon Ng Soo, 2019, UNESCO, Exploring STEM competences for the 21st century, https://learningportal.iiep.unesco.org/en/library/exploring-stem-competences-for-the-21st-century,2019).

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STEM is connected to digital economy as "economies increasingly globalize and digital technologies assume ubiquitous presence and functional utility in peoples' lives outside educational contexts", making necessary new pedagogies and instructional strategies as well as new competences (Kivunja, 2015).

In 2010, the President's Council of Advisors on Science and Technology (PCAST, 2010) announced that "*STEM education will determine whether the United States will remain a leader among nations and whether we will be able to solve immense challenges in such areas as energy, health, environmental protection, and national security*" and "*It will generate the scientists, technologists, engineers, and mathematicians who will create new ideas, new products, and entirely new industries of the 21st century. It will provide the technical skills and quantitative literacy needed for individuals to make better decisions for themselves, their families, and their communities*".

There are various different interpretations and suggestions of "STEAM education and STEAM integration" and numerous references indicate that STEAM education has been defined in different frameworks ranging from disciplinary to transdisciplinary approaches (English, 2016), indicating the need to articulate and delineate what we mean by STEAM integration, the type of STEAM epistemology, the evaluation in STEAM integration, the type of expected learning outcomes, the connection of STEAM integration with Computational Thinking practices etc.

Many researchers have worked for a conceptual framework for "integrated STEAM". (Wang et al., 2011; Sanders et al., 2012;Vasquez, et al., 2013; Guzey et al.,2017; Perignat et al., 2019;Tytler, et al., 2019; Quigley et al., 2019), indicating the need to clarify the "integrative STEM education." In order to delineate the concept of "STEAM integration" we have to proceed to issues related to Computational Thinking, Computational Science and the epistemologies of the disciplined included in the acronym of STEAM.

1. Computational Thinking(CT)

The term "computational thinking" was initially coined by Papert (1996) as procedural thinking operating as a medium to establish a relationship between a problem and its solution and the structuring of data (Cansu & Cansu, 2019). Wing made (2006) this term known by publishing an influential article. Wing (2006) defines computational thinking as "*Computational thinking involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer scien*ce", but a different definition was adopted in Wing (2011) as "*Computational thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent*". Despite the fact that there is no consensus for the components included in CT, abstraction is a fundamental component in many references (NRC, 2010; Yadav et al., 2014; ISTE, 2011; ISTE, 2016). Abstractions are considered as the mental tools of computing, necessary to solve the problem while different layers of abstractions are needed in order to solve problems on different levels (Wing, 2008). Sengupta et al. (2013) make an interesting suggestion for CT as "*CT encompasses being able to distinguish several levels of abstraction and apply mathematical reasoning and design-based thinking", and connect CT with Engineering design*". Piaget (1972) "*introduced the concept of reflective abstraction to describe the children's construction of abstract logico-mathematical structures and he distinguished three types of abstraction: empirical, pseudo-empirical, and reflective abstraction*".

According to Cetin &Dubinsyb (2017) reflective abstraction can be used as a tool in the study of computational thinking and they suggested that "*The most common meaning of* *abstraction of a concept in computer science and mathematics, is extraction, that is, the idea of considering common features of several examples and building a structure or category which has all of these features".* They also addressed the fact that another component of abstraction is decontextualization, as a way of thinking about a concept independently of any context which is what makes abstraction difficult.

We focus on abstraction, as it is connected to the development of models in the Computational Experiment paradigm and in the so called "Computational Problem"(see below) , in which learners are engaged in abstraction before the model development.

Dede, Mishra, and Voogt (2013), suggested the term "computational practices" in relation to CT, and considered that "*Computational thinking requires understanding and applying abstraction at multiple levels ranging from privacy in social networking applications, to logic gates and bits, to the human genome project, and more. Students in this course use abstraction to develop models and simulations of natural and artificial phenomena, use them to make predictions about the world, and analyze their efficacy and validity*". We notice that CT is considered as fundamental in developing models which is the core of the Computational experiment(see below)

There is also a lot of research effort to connect STEAM-as an integrated approach- to CT. This connection is based mainly on the role of modeling and the collection and analysis of data produced after implementing the model. Kong (2014) considered that CT has an essential role in STEM as it can cause a deep understanding of STEM content areas for students (Guzdial, 1994; National Research Council, 2011; Repenning et al., 2010; Sengupta et al., 2013; Wilensky& Reisman, 2006) and make them get engaged in a reflective mode cultivating their problem solving and logical thinking ability. In this article, there is a specific notion on computational modeling as a vehicle for learning STEM concepts (Sherin, 2001; Hambrusch et al., 2009). Another approach for the relationship between CT and Science education is proposed by Weintrop et al. (2016). In specific, Weintrop et al. (2016) proposed a model for CT and Science Education based on Computational Models and Computational Problems in the form of a taxonomy consisting of four main categories: data practices, modelling and simulation practices, computational problem-solving practices and systems thinking practices.

Moreover, Pedaste & Palts (2017) discuss the concept of computational learning as an iterative and interactive process (between the student and the model of computation).Later, we will propose that CT can play the role of "boundary objects" between STEAM disciplines. Succinctly, CT plays a fundamental role in model development in the Computational Experiment approach, described in the next section

2.Computational Science

In this section, we discuss in detail the different terms appear in literature related to STEM and we try to delaine them. There is a lot of research-and confusion- about the terms "computing", "computation" and "computational". In research papers these concepts are used being similarly while in some others they are differentiated (implicitly or explicitly) (Psycharis, 2018a, b). According to Wing (2008), computing is the field that encompasses computer science, computer engineering, communications, information science and information technology.

The term "computation" appears also in different settings. Jona et al. (2014) state that "*Computation is an indispensable component of STEM disciplines as they are practiced in the professional world. In the last twenty years, nearly every STEM field has seen the birth or reconceptualization of a computational counterpart, from Computational Engineering and Bioinformatics to Chemometrics and Neuroinformatics*". Despite the fact that, the terms "computation" and "computational" are used interchangeably, we consider that "computing" is included in "computational".

Denning (2009) states that "*the Great Principles of Computing are: computation, communication, coordination, recollection, automation, evaluation, and design*", i.e. computation is a component of computing. The term "computational tools" also appears in many papers but without a clear definition of its content and use and without distinguishing it from computing (Weintrop et. al, 2016).

Jona et al. (2014) state that "*one of the fundamental research questions in the STEM agenda is —with the STEM approach, how can we increase computational competencies for all students and build interest in computing as a field in its own right?*", connecting "computing" with "computational tools", while Chande (2015) considers that nature can be explored by computational activities.

Barr & Stephenson (2011) consider that "*Computer Science is related to Computational processes and scientists can promote understanding of how to bring computational processes to bear on problems in other fields and on problems that lie at the intersection of disciplines. For example, bioinformatics and computational biology are different, but both benefit from the combination of biology and computer science. The former involves collecting and analyzing biological information. The latter involves simulating biological systems and processes*".

According to Yasar et al. (2016), "*computational pedagogy is an inherent outcome of computing, math, science and technology integration, and this view is close to our consideration*". In the same article computing is related to algorithmic and programming.

They, also, suggest that computational modeling and simulation technology (CMST) can be used to improve technological pedagogical content knowledge (TPACK) of teachers. Close to our consideration is the view of that "*projects with an orientation to computational science tend to emphasize data, modeling, and systems thinking*". From the brief analysis presented, it is evident that the terms computing, computation, computational are used sometimes with the same meaning (i.e. algorithms, make calculations etc) and in other cases computational means something wider than computing (Bienkowski et al., 2015). Our view is that the term "computational" is more "dense" and its origin comes from the 'Computational Science", rather than the Computer Science. Next, we focus on the Computational Science epistemology, as it plays a fundamental role in our suggestion for the STEAM integrated approach.

Computational Science (C.S.) "*is the integration of Mathematics, Computer Science and any other discipline to explore authentic-complex problems bringing together concepts from a variety of cognitive subject*s" (Landau et al., 2008) while is considered to be part of the Computational Science-Engineering community (Psycharis, 2015).

Wolfram (2002) also proclaimed "*the emergence of a new kind of science based on computational experiments into emergent patterns in nature, arguing such explorations are not possible without computation*" (as cited in Weintrop et al., 2016), emphasizing that a new experimental approach has emerged due to the development of highly detailed computational models leading to a new kind of science based on computational experiments.

Computational Science (C.S.) overlaps many other knowledge areas, so an educational program in Computational Science, naturally draws strength from all of them (Yasar, 2004; Yasar, 2013; Yasar & Landau 2003). Nevertheless, in addition to over-lapping with computer science, math, and science and engineering application areas, Computational Science has its own core knowledge area and core concepts

Juszczak (2015) makes a significant remark for the epistemology of Computational Science, by considering that is "applicable" to both natural and social sciences and that Computational Science is different than the usage of computers to analyze complex systems and data sets. The author proclaimed that Computational Science is a non-empirical science, since data that was gathered in Computational Science is the result of simulations and virtual experiments and he goes one step further by making clear that the key distinction between a true computational science and a science that uses computation, is in the nature of evidence: "traditional science and science experimentation that use computation to assist in the analytic and experimental process have, as their threshold of truth, empirical evidence". In Computational Science the experiments are virtual and the data are real and the computational experiment is equivalent to the usual experiment on the laboratory. On the other hand, computational experiments attempt to use data about the real world in order to conduct real experiments in a virtual universe.

3. Epistemology of STEAM Disciplines

Understanding of the epistemologies of the disciplines included in the acronym of STEAM is a prerequisite for engagement of learners in the practices of these disciplines and the discovery of the boundary objects that can serve as tools to "cross' the disciplines and lead to "STEAM integration".

Generally, epistemology is defined as the way that people acquire, justify, and use knowledge. According to Chandler et al. (2011), epistemology is a way of reasoning, knowing and understanding the entities we encounter in the world. Education epistemology is considered as the epistemology made up of experiences, formal and informal instruction, and assumptions about education. Epistemology is also considered as a branch of philosophy concerned with the nature and justification of human knowledge. We start with the epistemology of the Technology.

Kroes& Van de Poel (2009) raise the issue of the dynamics between Tchnology and society and whether we can conceptualize these as different entities. Their analysis ends with the conclusion that they cannot be separated. Our view is that this conclusion could serve as a good justification to relate the real problems of society with the STEAM disciplines and the ultimate aim of "STEAM integration" to resolve issues related to society.

According to Kroes&Van de Poel (2009), there are two meanings of Technology, namely:

1)" *technology as process (activity): technology as the collection of processes of designing, developing, producing, maintaining and disposing of technical artefacts,*
and
2) technology as product (object): technology as the collection of technical artefacts,
that is, what comes out of technology as a process in so far the latter is restricted to the design, making and maintenance of technical artefacts".

It is worthwhile to refer to the Canadian scientist and public philosopher Ursula Franklin (1999), who argued that Technology can be best understood not as a set of tools but as a contextually embedded practice. According to Sengupta &Shanahan (2017), "*This perspective implies that technology should be viewed not only as ways and means of performing disciplinary work, but also in light of broader norms of participation in disciplinary and ancillary cultures that develop around localized technological infrastructure*". Next we present the Engineering epistemology.

Engineering epistemology is made up of lived experiences, formal and informal knowledge and assumptions about the discipline of Engineering. The discipline of Engineering can be divided into Engineering content and Engineering design (as an iterative cycle). "*Engineering content emerges from the intersection of science, mathematics, and necessity comprising a collection of tools, which engineers can useto design solutions to specific problems based on criteria and constraints*" (Shirey, 2017). *Engineering uses the well known engineering design cycle (*Massachusetts science and technology/engineering curriculum framework https://www.doe.mass.edu/frameworks/scitech/2016-04/AppendixI.pdf)in alignment with the Scientific Inquiry in the form of the following practices.

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information (https://www.doe.mass.edu/frameworks/scitech/2016-04/AppendixI.pdf)

According to Rugarcia et al. (2000), "*engineering education includes the development of engineering knowledge (facts and concepts), engineering skills in the form of design, (computation, and analysis), and attitudes (values, concerns and preferences*)".

4. Core and Transverse Concepts, Threshold Concepts and Boundary Objects

Our proposal for STEAM integration is based on the crosscutting (transverse)concepts. According to (NRC, 2012) "*science education in grades K–12 should be built around three major dimensions: science and engineering practices, crosscutting concepts that unify the study of science and engineering through their common application across fields, and core ideas in the major disciplines of natural science*".

In NGSS (2013), the crosscutting concepts are extensively presented and described, and include: 1. Patterns 2. Cause and Effect 3. Scale, Proportion, and Quantity 4. Systems and System Models 5. Energy and Matter in Systems 6. Structure and Function 7. Stability and Change of Systems. These concepts can be conceived "*as an organizational structure to understand the world and help students*". Every discipline is based on the core disciplinary concepts, but amomh them the threshold concepts play a crucial role in teaching and learning.

Threshold Concepts (TCs) are of particular interest to Science and STEM education, representing a "*transformed way of understanding, or interpreting or viewing something without which the learner cannot progress.*"(Psycharis, 2016)

Threshold Concepts are often labeled as "troublesome" concepts, indicating that these concepts are troublesome, but at the same time essential to knowledge and for understanding within particular disciplines (Loch & McLoughlin, 2012). According to Meyer & Land (2003), "*threshold concepts (TCs) can be considered as akin to a portal, opening up a new and previously inaccessible perspective of thinking about concepts and phenomena*." Meyer & Land (2003) identified some characteristics of threshold concepts, namely: "*Threshold concepts are transformative (occasionally triggering a significant shift in the perception of a subject), probably irreversible (unlikely to be forgotten), integrative (learners perceive previously hidden relationships), troublesome (threshold concepts embody knowledge that is troublesome for learners to grasp, knowledge of these is counter-intuitive, and cannot be easily integrated with the learner's current mental schema) and often disciplinarily "bounded" (a threshold concept will probably delineate a particular conceptual space, serving a specific and limited purpose*".

Not all of the disciplinary core concepts are threshold concepts. Identifying which disciplinary concepts are threshold concepts can help to include them in the crosscutting concepts and this is our idea, i.e. to apply didactic scenarios with scientific and engineering practices including crosscutting concepts and threshold concepts. To complete our prerequisites for the STEM integration we have to talk briefly for the boundary objects.

One of the issues raised for inclusion and determination in STEAM integration includes the concept of boundary objects (Star,1988; Star, 2010; Star & Griesemer, 1989). Boundary/crossing objects are concepts used to analyze the ways in which experts in multiple fields interact (Engestrom et al., 1995; Polman & Hope, 2014).

Another interesting conclusion for boundary concepts-and, in our opinion, very useful in determining practices in STEAM integration-comes from Akkerman & Bakker, (2011). They suggest that the concept of the boundary object refers to artifacts achieving the crossing by fulfilling a bridging function. Engestrom et al. (1995), refer to boundary objects as concepts used to face the challenge of negotiating and combining ingredients from different contexts to achieve hybrid situations".

The use of boundary objects in science education has been discussed in research papers, as something connected with the "transfer". For example, Saljo (2003) proposes that transfer is a concept used to study "*what is learned and for questioning how something learned in one task or context is applied in another task or context*" (as cited in Akkerman & Bakker, 2011).

Leung (2020) discusses very clearly the relation of boundary objects with STEM integration, justifying their utility by the fact that "*Learning as production of practices creates knowledge boundaries. A key concept to address the complexity of the integrated STEM pedagogy phenomenon is boundary crossing among different knowledge domains. Mediating objects are needed to bridge the disciplines*". We consider that boundary objects are not "static" in STEAM integration and their propagations through the STEAM disciplines determine their effectiveness. Later, when we will discuss the STEAM integration, we will propose boundary objects.

5. Instructional Strategies in STEAM Integration

Integrated STEAM instructional strategies are at the core of research in STEAM, alongside with issues related to evaluation. Taking into account the different epistemological approaches in STEAM integration, we will briefly present the instructional strategies with the aim to take into consideration the so-called STEAM competencies and the corresponding learning "STEM integration" outcomes.

According to Thibaut et al. (2018) STEM integration in the curriculum would resolve issues like restructuring of the curriculum, the knowledge teachers should have and their training, the pedagogical content knowledge needed, the resources needed at schools and the kind of learning outcomes that should be evaluated.

Research papers discuss and provide examples for STEAM integration but they do not usually provide theoretical considerations of these strategies (Moore et al., 2014a,b; Sanders, 2009, 2012) and without the possibility of generalization (Becker &Park, 2011; Gresnigt et al., 2014). Another interesting issue is the lack of reference to the background learning theory(theories) that supports the teaching strategy. In the last years one basic instruction strategy for Science Education was the Inquiry based Teaching and Learning approach. Inquiry based Science Education has been implemented for many years and focus on Inquiry based learning while it officially been promoted as a pedagogy for improving STEM learning in many countries (Bybee et al., 2008) and can be defined as "*the deliberate process of diagnosing problems, planning experiments, distinguishing alternatives, setting up investigations, researching conjectures, sharing information, constructing models, forming coherent arguments, collecting and analyzing data*" (Bell et al., 2004). Engineering education in STEAM, through its core concepts and epistemology, leads to consideration of Engineering design -based learning as another instruction strategy engaging students in solving authentic, ill-defined problems that require the integration of theory and practice as well as the engineering practices (Grubbs &Strimel, 2015).

Scientific Inquiry and Engineering design-based learning are both necessary for STEAM integrated strategies and a clear and practical approach for their intersection is described by

Apedoe et al. (2008). The authors propose the so called designed-based learning (DBL), combining engineering design with a scientific inquiry based teaching and learning approach. Research indicates that engagement of students in design-based learning activities combined with scientific activities can result in the development of problem solving and scientific inquiry skills (Kolodner et al. 2003; Apedoe et al., 2008) while science and design activities overlap in the so called Public Dialogue space (Apedoe et al., 2008). Succinctly, "*scientific inquiry and engineering design activities should be mutually reinforced in the form of ,for example, data generation using scientific inquiry that will inform engineering design decisions*" (Katehi, Pearson&Feder, 2009).

6. STEM Integration-Computational Integrated STEAM Pedagogy

We have presented computational thinking practices, computational science, computing, the scientific and engineering practices, the crosscutting and threshold concepts as well as the boundary objects. Our aim is to propose a Computational STEAM integration by combining all these and clarify their role in the integration.

There are a lot of concerns about STEAM integration. These concerns have been raised due to the different epistemological approaches adopted in STEAM integration (mainly interdisciplinary or/and transdisciplinary),while the practices of Artists are in deep consideration in relation to the inclusion of Arts in STEAM integration.

In some cases, there is lack of consensus related to the details of integrators included and even at the exact meaning of interdisciplinarity or transdisciplinary in relation to STEAM integration. Accordingly, different terminologies have been proposed, while almost all of them engage the engineering design as an integrator.

Different approaches have been proposed (Wang et al., 2011; Sanders etal., 2012; Vasquez, et al., 2013; English, 2016; Guzey et al., 2017; Perignat et al., 2019; Tytler, et al., 2019; Quigley et al., 2020; Bryan &Guzey, 2020; Bryan et al., 2015; Psycharis,2021), indicating the need to clarify the "integrative STEAM education". Moore (2008) proposed two models of STEM integration: *content integration* and *context integration*. "*Content integration focuses on the merging of the content fields into a single curricular activity or unit to highlight "big ideas" from multiple content areas*".

We should state that we use the term "STEAM integration" to refer to a model that integrates computational science, computational thinking dimensions (concepts and practices), scientific and engineering practices with threshold and crosscutting concepts by the use of boundary objects.

The integrators (which bring together these concepts) are the scientific and engineering practices and the threshold -disciplinary concepts-as well as the crosscutting concepts where boundary objects are used through the implementation of computational models in order to solve an authentic problem. Within this framework, data collected through different methodologies (e.g. physical computing) are real, and the "experiment" is equivalent to the usual experiment in the lab.

We also suggest a "Computational STEAM approach" in which the boundary objects are not static. Rather, their nature changes during their propagation through the discrete discipline due to the interaction of the boundary object with the threshold concepts of the particular discipline. The epistemology used is interdisciplinary (in the case of the inclusion of Arts it could be transdisciplinary) where the STEAM content approach is implemented, i.e. through the development of a single curricular activity.

Our approach for STEAM integration is based on interdisciplinarity as " *a fusion of the four disciplines of Science, Technology, Mathematics and Engineering, where the focus of learning is not the individual discipline in itself, but on solving real-world problems*" (Boon Ng, Soo, UNESCO, Exploring STEM competences for the 21st century, https://learningportal.iiep.unesco.org/en/library/exploring-stem-competences-for-the-21st-century, 2019) where the focus is on a shared concept from the crosscutting concepts (Boon Ng, Soo,UNESCO, Exploring STEM competences for the 21st century, https://learningportal.iiep.unesco.org/en/library/exploring-stem-competences-for-the-21st-century, 2019). In this approach identified threshold (disciplinary) concepts are investigated and handled through a didactic scenario based on the "STEAM content" approach and computational thinking dimensions (concepts and practices), where they will appear as discontinuities in the cognitive part as well as at the practices of students. Our suggestion is to start with a single curricular activity based on the transversal concepts and include the threshold -disciplinary-concepts. Computational Science and computational thinking should be employed to collect data as a real experiment applying the scientific and engineering dimensions.

The Figure below presents our model (modification of (Watson&Watson, 2013)

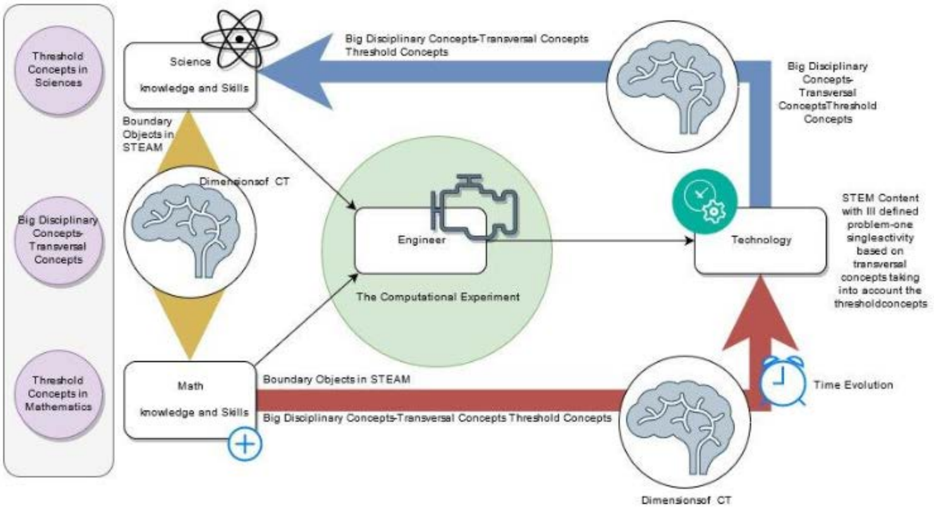

Figure: The Computational STEAM with border objects

7. Examples of STEAM content epistemology based on transversal concepts

We briefly describe two examples that are in alignment with the STEAM content-based approach and the interdisciplinary epistemology while the "core" concept is one or more transversal concepts.

One example refers to the concept of periodicity.

The core of the activity is related to the concept of the "period". This concept appears in many sciences in a different context and engagement of students in activities which contain the period can enhance their knowledge for concepts that determine the period of a phenomenon. The concept of "period" is also related to the crosscutting concepts through for example the investigation and discovery of patterns.

Concepts related to the period could be embedded in many transversal concepts, like system and subsystems, cause and effect and-of course- the recognition of patterns.

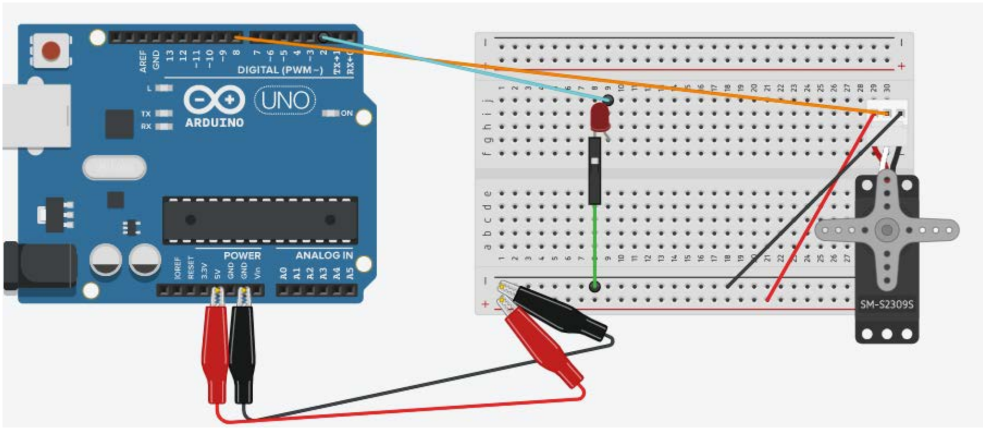

Figure. Connection of LED with a servo and the Arduino platform.

The problem should be stated as follows. Imagine you have a servo motor and you want to design a system which responds to the rotation of the servo as follows. When the angle of rotation increases the LED is switched on and when the angle decreases the LED switches off.

We can implement this artifact using the LABVIEW (https://www.ni.com/en-us/shop/labview.html).

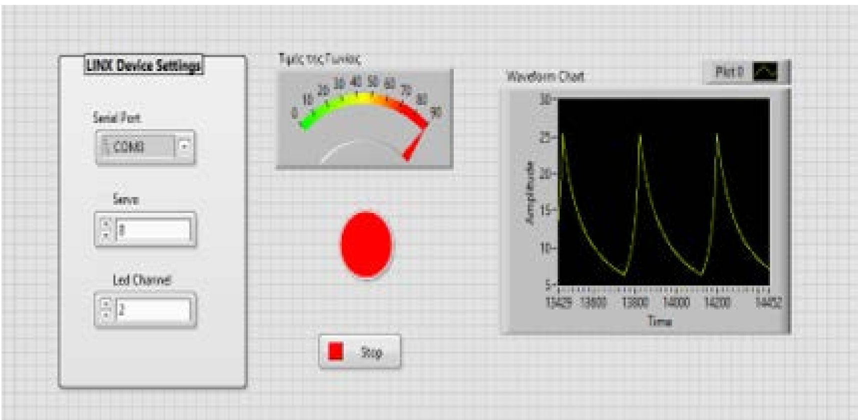

Figure. Connection of LED with a servo and the Arduino platform in Labview

Another example is the Art Gallery problem. The ill-defined problem that should be solved is: Can you design an artifact which will switch on the light when a system will rotate with a specific frequency? Can you think how this alarm system will be implemented with low cost for the protection of a museum?" This problem is also related to Mathematics and implements the practices of Computational Thinking like, pattern recognition, decomposition of the problem etc.

The Mathematics enter through the well known problem "the art gallery problem"**https://wild.maths.org/art-gallery-problem**.

"*The problem was first posed to Václav (Vašek) Chvátal by Victor Klee in 1973 and was stated as:*

Consider an art gallery, what is the minimum number of stationary guards needed to protect the room? In geometric terms, the problem was stated as: given a n-vertex simple polygon, what is the minimum number of guards to see every point of the interior of the polygon?" (Chesnokov, 2018)

One simple solution was presented by Steve Fisk using a 3-coloring argument. We divide the space in triangles in simply connected regions, each of which can be seen by a single guard, where the guards are places at the vertices, in such a way that guards have a whole view of the polygon.

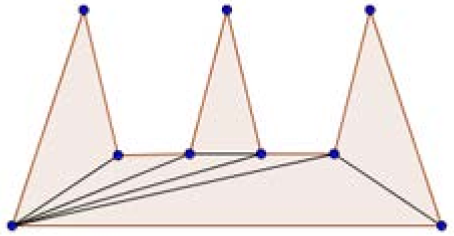

Figure. The Art Gallery problem (https://wild.maths.org/art-gallery-problem).

The solution proposed by Steve Fisk was based on the idea to "colour the vertices using three different colours so that every individual triangle has no two vertices coloured in the same colour. Next, choose a particular colour, say blue, and place a guard at each vertex coloured in that colour. Since every triangle has exactly one blue vertex, this gives us one guard for each triangle, so this placement of guards makes sure they can together see the whole gallery"(https://wild.maths.org/art-gallery-problem).

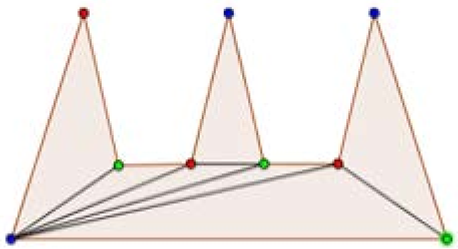

Figure. The Art's Gallery problem solution (https://wild.maths.org/art-gallery-problem).

This problem contains transversal concepts like patterns, scale, structure and CT practices, like pattern recognition and abstraction. Generalization is included through the engagement in solving the problem for more "crazy" shapes. Guards can be replaces by sensors in Arduino and students are engaged in the study of concepts like infrared radiation , communication od sensors as well as the Internet of Things.

8. Conclusions and recommendations

Over the last two decades, the form of STEAM epistemology, the different approaches for the STEAM integration, the learning objectives that should be included in STEAM integration as well a the "tools" needed to implement the integration are at the priorities in the policy makers and researchers in all over the world.
In this paper we have discussed and analysed briefly the different epistemologies included in STEAM integration and we proposed a model based on the Computational Science and the border objects that cross the separate disciplines. Border objects include the CT dimensions and the disciplinary threshold concepts, while our view is that interdisciplinary has at its core one or more crosscutting concepts.
We consider that further research should be conducted -with proper evaluation tools-in order to delineate the form of STEAM integration.

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Θέμα: Fwd: Αλλαγή κατάστασης εργασίας σε αποδεκτή
Από: psycharis_sarantos psycharis_sarantos <spsycharis@gmail.com>
Ημερομηνία: 21/4/2021, 11:18 μ.μ.
Προς: ΚΩΝΣΤΑΝΤΙΝΟΣ ΚΑΛΟΒΡΕΚΤΗΣ <kkalovr@gmail.com>

---------- Forwarded message ---------
Από: **STEAM2021Conference** <steam2021conference@easychair.org>
Date: Τετ, 21 Απρ 2021 στις 9:49 π.μ.
Subject: Αλλαγή κατάστασης εργασίας σε αποδεκτή
To: Sarantos Psycharis <spsycharis@gmail.com>

Αγαπητοί συγγραφείς,

μετά τις διορθώσεις που κάνατε η εργασίας σας έγινε αποδεκτή στο συνέδριο.
Σας ευχαριστούμε για τη συνεργασία.

Εκ μέρους της επιστημονικής επιτροπής του συνεδρίου.

Γκινούδη Αθηνά
Μπαλωμένου Αθανασία
Συρρής Ιωάννης