From Trivium to Smart Education

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Abstract. Rethinking the classics for thinking the future. This could be the compendium of the present article, in which we propose a revision of the immediate future of education based on the classic project of the Trivium. We will analyze, first, the transformation of education in the perspective of *smart education,* determined by the impact of technology and by the reflection on the competences of the 21st century; secondly, we will review the strategic and methodological proposals in accordance with this transformation, based on the theory of generative learning; thirdly, from the point of view of contents, we will analyse the importance of core digital skills as programming and computational thinking.

On this basis, the paper offers a proposal from a dual perspective. Firstly, by rethinking the main issues of education in the light of the history of the Trivium and the epistemological principles that shaped it. Secondly, by proposing the recovery of the Trivium disciplines (Grammar, Rhetoric and Logic) having in mind the debate on the competences of the 21st century, as the best instrument to enrich the current educational systems, especially in view of the challenges of digitalization.

Keywords: Smart education · Trivium · Competences · Computational thinking

1 Introduction

The immediate future of education is determined by the exponential impact of technology. This transformation of education is leading to what the International Association of Smart Learning Environments (IASLE) has defined also as: "an emerging area alongside other related emerging areas such as smart technology, smart teaching, smart education, smart-e-learning, smart classrooms, smart universities, smart society. The challenging exploitation of smart environments for learning together with new technologies and approaches such as ubiquitous learning and mobile learning could be termed smart learning" [23].

In recent years, some voices have emerged calling for a look at the Trivium, both from the point of view of learning skills [16,20] and from that of interdisciplinary studies [5], as an inspirational source for facing the educational challenges

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of the 21st century. In this article we propose a revival of the classic Trivium project, both from the point of view of the philosophical reflections that emerge from its historical revision, as well as from the point of view of the content of the disciplines that compose it.

The term Trivium, whose first vestige of use dates from the 9th century [32], means "triple road" and includes the first three of the seven liberal arts, that is, Grammar, Rhetoric and Logic, which constituted the corpus of literary knowledge, today we would say humanities, from Antiquity to the Renaissance. Subsequently, these disciplines maintained an unequal presence in the faculties of arts [6] and, finally, when they were relocated at different rates within the framework of modern and contemporary education, they lost their central position. As a result of this process, Rhetoric and Logic are occupying today a residual place in the curricula, being accessible only under the specialized or complementary training modalities [36].

With this basic conceptualization, the reminder of this paper is organized as follow. In Sect. 2 we analyze the transformation of education in the perspective of Smart Education; in Sect. 3, we present some pedagogical and methodological issues of this transformation in the light of the theory of generative learning; at Sect. 4, we analyse the importance of computational and algorithmic thinking as well as programming, as key elements of digital skills; Sect. 5 is devoted to show how the classical Trivium concept can help us to face challenges in education today; Sect. 6 concludes setting out the main findings of this approach.

2 Smart Education and Education for the 21st Century

Zhu *et al.* [39], defined smart education this way: "The essence of smart education is to create intelligent environments by using smart technologies, so that smart pedagogies can be facilitated as to provide personalized learning services and empower learners, and thus talents of wisdom who have better value orientation, higher thinking quality, and stronger conduct ability could be fostered". According to Coccoli *et al.* [9], the environments of intelligent education are characterized by their richness, interactivity and flexibility, in order to be able to fulfill three objectives: (1) To take advantage of the devices availables in networks, (2) To enhance individual skills and competences (3) To reinforce collaborative work.

The consequences of this novelty take place on two levels, *objective* and *subjective*. On the *objective* level, it confronts individuals with situations for which, in principle, they lack tools and conceptual schemes. This objective novelty encompasses the personal sphere, as it is progressively immersed in an environment dominated by artificial intelligence; the work sphere, as it is constantly faced with a variation and complication of work profiles [30]; and the social sphere, as it is subjected to the dynamics of intense social mobility and forms part of the entrepreneurship competence [2], as well as of the new social and civic space defined by the elements of digital citizenship [13]. Education, therefore, must provide a high level of adaptability through polyhedral labor profiles, with

a wide range of complementary skills and competences as citizens as well [35]. The model of education focused in reproducible protocols must be enriched with instruments to connect concepts and create knowledge adapted to new problems [25,26].

This brings us closer to the second level of consequences, that is, the *subjective* changes involved, since they produces a situation of insecurity and uncertainty that, in itself, constitutes an obstacle to the effectiveness of individual actions and decisions. This idea is emphasized by Segredo *et al.* [35]: "Citizens of the future must have full confidence in the tools and technologies involved in a smart environment". Thus, an adequate training must be an instrument of personal success also subjectively, favouring attitudes and feelings of self-confidence and security. This can be achieved by promoting key skills such as creativity or resilience at NMC Horizon Report [28] and all of these abilities, in short, that allow people to develop and "live effective at work and leisure time" (Trilling & Fadel [37], Zhu *et al.* [40]). Technology in education, therefore, is revealed in this context as fundamental, but not enough. Segredo *et al.* [35] provide us with a precise and illustrative synthesis of recent reflection on competencies for the 21st century, which outlines its main lines by determining dimensions, skill levels, main components, basic academic goals, and ICT skills. These works shows that technology should be a fundamental tool, but not the ultimate goal. Education must therefore serve to go further and develop a new digital citizenship, taking into account the concepts of social responsibility, quality of life and, ultimately, personal happiness. All of this has been object of the European report on social and emotional education conducted by Cefai *et al.* [12].

3 Methodology, Design and Educational Environment

With regard to smart education, Zhu *et al.* [40] identify three essential elements, that is, environments, pedagogy, and learners, while a main requirement: to provide higher thinking quality, and foster stronger conduct ability. According to this, Segredo *et al.* [35] highlight three methodological needs: (1) The design of learning processes according to the needs and preferences of the students. (2) The application of a generative learning model in which, instead of giving priority to the reception of transmitted content, the active role of the student is the main factor, who acts supported by the educational potential of the intelligent environment and (3) The design of intelligent environments according to a constructivist paradigm. This is also the main component of the third and fifth areas of competences of the European Framework for the Digital Competence of Educators [33].

Nonetheless, our tradition of teaching [21], in which personal presence and living word are primordial, together with the fact of the natural reticence to change of the educational systems, could be precisely at the basis of the "the consistent tendency of the educational system to preserve itself and its practices

by the assimilation of new technologies into existing instructional practices", in such a way that technology is domesticated within the framework of the "prevailing educational philosophy of cultural transmission" [35].

4 Digital Skills, Computational Thinking and Educational Content

Since its first formulation at 2006 by Jeannette Wing [38], definitions of computational thinking have shown discrepancies about its basic components, but it exists a fundamental consensus that becomes visible, for example, in how the International Society for Technology in Education (ISTE) and, likewise, the Computer Science Teachers Association (CSTA), identify the core dimensions of computational thinking: 1. Formulate problems with a view to their solution by means of computers. 2. Organizing and analyzing data logically. 3. Representing data through abstractions, models, and simulations. 4. Automating solutions through algorithmic thinking, that is, through a series of steps ordered to those solutions. 5. Identify, analyze and implement efficient solutions. And finally 6. Generalize the solution process to a wide range of problems [35].

Bocconi *et al.* underline also the definition proposed by the Royal Society in 2012, in which "stresses that computation is not exclusively a human construct but is also present in nature": "Computational thinking is the process of recognising aspects of computation in the world that surrounds us, and applying tools and techniques from Computer Science to understand and reason about both natural and artificial systems and processes".

Algorithmic thinking, in turn, also used in many official policy documents to refer to CT [4], implies the following skills: 1. Analyze given problems. 2. Specifying or representing a problem accurately. 3. Finding the basic and appropriate operations (instructions) to solve a given problem. 4. Constructing an algorithm to solve the problem following the given sequence of actions. Think of all possible cases (special or not) of a given problem. Improve the efficiency of an algorithm [35].

"Fostering coding and programming" is one of the six main reasons to introduce computational thinking in curriculum [4]. But because provided that programming teaches thinking and this teaches to think in general, it results that programming and computational are mutually reinforcing strategies that benefits education.

Actually it has become clear that an effective way to improve educational content in general while digital skills also is by incorporating models of Computational Thinking (CT). The development of CT on this perspective goes along the thinking over these models, algorithmic thinking and programming [7].

Finally, among the reasons to introduce computational thinking in curriculum, stand out for us the two following: (1) CT foster logical skills and (2) CT foster 21'st skills as entrepreneurial skills, social and emotional skills [4].

5 Why a Revival of Classical Trivium to Face 21st Century Education Challenges?

5.1 Trivium Insights: Philosophical Reflections Emerging from History

At least five main blocks of questions emerge from the above considerations, in relation to which a retrospective look at the classical world [24] and the contents of the Trivium can help us to shed light:

The Need to Include Digital Skills in a Broad Sense in Educational Design. One of the most striking methodological problems facing contemporary education are operational and organizational difficulties produced by the amount of disciplines [4]. The need to introduce digital competencies in a broad sense and the lack of consensus aggravates the problem of the comparability of education systems. In the absence of a concept of unity of knowledge, it makes more visible the voluntarist nature of the requirements of interdisciplinary studies, that claim, for example, a naif substitution of STEM by STEAM (STEM + Arts) [22]. A careful look at the history and components of the Trivium can help us to shed light on these problems, pointing to an integral solution that starts from their common root: the idea of unity of science, nature and mind. The disciplines of the Trivium (grammar, rhetoric, logic) and those of the Quadrivium (music, astronomy, geometry and arithmetic) formed a coherent and complete whole ('enkiklios paidea', encyclopedic cycle of knowledge) with a common epistemological foundation: mathematics [21]. In this same direction, on the interweaving of mathematics and philosophy in the Quadrivium, the recent study of Sanna (2019) [34].

This fundamental idea of a coherent and organized whole is what emerges, for example, in *four moments* of prehistory and the history of the Trivium that we will now comment on.

The *first* is Plato's Philebus (18c), when Socrates invokes the number as the origin of the invention of Grammar, mythically attributed to the god Teuth [31]. The *second* is the commentary of the neo-Platonic Proclo (412–485) on the first book of Euclid's Elements [21]: "The importance and usefulness of mathematics for the other sciences and arts, we can learn it if we think how mathematics imposes perfection and order to theoretical sciences such as Rhetoric and to all those that are executed through discourse". The *third* is Book II of the *De Ordine* of St. Augustine (354–430), where the origin of all knowledge (and, therefore, also that which is consecrated to the study of "the meaning of words", that is, the three disciplines of the Trivium) is attributed to the activity of "reason" (which today we could translate as intelligence), which finds all its "strength" and "power" in "numbers" [1,21]. From this epistemological perspective, reinforced by the essential connection of programming languages with logic, a possible solution for the integration of digital literacy could be developed through the inclusion of transversal contents related to this epistemological unity, specially contents of Logic. The *fourth* takes us back to the 14th–15th centuries, in

relation to the integration of humanistic and scientific knowledge carried out by Renaissance humanism and, in particular, by Salamanca humanists as Nebrija or the Brocense [15]. The Humanities do not represent certain human knowledge as opposed to others that are inhuman or dehumanized due to their scientific or technical nature. Thus, Ptolemy's Geography and Euclid's Elements of Geometry were as humanistic as Virgil's Aeneid or Plato's Banquet.

The Need to Include Communication and Critical Thinking Skills. As Segredo emphasizes [35], the majority of the approaches on 21st century skills stands out the importance of writing, critical and inventive thinking, communication, problem solving and teamwork skills. This highlights the importance of classics tools that includes Rhetoric (invention and arrangement, understanding emotions, argumentation, style an ornament, memory and delivery), what it can be found in all the literature, from classical antiquity to the present day [27].

Technology is Essential but it is Not Enough. The same idea emerges strongly in two of the most famous myths found in Plato's works, the myth of Prometheus and the myth of Theuth. "The theft of Prometheus is not enough to guarantee full human life. It only serves for human nutrition, so that man becomes a craftsman, a builder or a farmer, but not all professional arts together guarantee human coexistence" [17]. The insufficiency of specialized technical knowledge is also the theme of platonic version of Theuth's myth, whose moral is that not everyone who has been given something to discover, has also been given to understand the importance and convenience of their finding. In the same way that for Theuth the possibility of writing down science and history meant a revolutionary milestone of human consciousness and evolution, the present era hopes that the development of technology will make it possible, not just an advance without precedents of knowledge, but even a qualitative leap forward in the evolutionary history of the human species [14].

Previous Training of a Basic and Propaedeutic Nature, Including Literary and Humanistic Training, Is Necessary. This idea responds precisely to the idea of paideia as "general culture", basic and preparatory to any higher specialization, as well as necessary for the maximum development of the personality [5,21].

A Global and Comprehensive Design is Needed, Without Splits, Coherent, Defining a Progressive, Interdisciplinary and Complementary Skills Curriculum. The cycle of the seven liberal arts, the first part of which is the Trivium, was conceived as a whole of knowledge of a universal, coherent and internally connected interdisciplinary nature. A cycle of learning and training that is a direct continuation of the tradition of the *enkyklios paideía*, characteristic of Hellenism, which was joined by Cato (*Ad Marcum Filium*), Varrón (*Disciplinarum libri novem*) and, thereafter other authors as Macrobio, Boethius, Marciano Capela, Cassiodorus and Isidor of Seville [21].

5.2 Rationale of Rhetoric and Logic as Components of 21st Century Curriculums

Assuming the importance of digital skills like programming and computational thinking from the point of view of education in general (Sect. 4), is now a matter of exposing the reasons why the disciplines of the Trivium are decisive in promoting and optimizing the transformation of educational systems as proposed by Segredo *et al.* [35]: "that computational thinking may be used as a more general learning methodology, not uniquely devoted to those interested in a professional career in the field of Computing, but also *for every learner interested on training useful and promising skills*".

Our proposal to recover the scheme of the Trivium is based on the fact that the disciplines that compose it fulfil a double function: on the one hand, they reinforce the skills of computational thinking, algorithmic thinking and programming; and on the other hand, they develop the main skills of the 21st century that are not technological.

Given the fact that the study of Grammar and Literature has been preserved in current educational systems, our proposal is focused on Rhetoric and Logic, which today we would call formal and informal logic [10].

Rhetoric. As indicate above (Sect. 5.1), the five basic skills [27] that make up the instruments of classical Rhetoric cover almost all the competences of the 21st century by Segredo *et al.* [35]. We underline the following:

- *Invention*: reading, writing, thinking and problem solving, creativity, cognitive abilities or higher-order thinking skills innovation, information literacy, productivity and accountability.
- *Disposition*: master information, prioritizing and planning.
- *Elocution*: reading, writing, creativity, cross-cultural interaction
- *Memory*: cognitive abilities, productivity and accountability.
- *Action*: emotional skills, communication and collaboration, initiative and self-direction, leadership, responsibility, effective communication.

Next, we will explain in more detail the benefits of sequentially introducing Logic among educational contents in two specific versions: first, syllogistics logic [10], and second, the algebraic version of Fred Sommers' Aristotelian logic (TFL - Term Functor Logic) [18,19,29].

Syllogistics Logic. Its advantages from the perspective of current educational challenges [10,29], can be summarized as follows:

- Being a logic that uses natural language, facilitates learning, or otherwise reduces the cognitive load.
- Its basics operations opens access to the understanding of reality from abstract categories and, therefore, to the operations of formulation, organization, representation, abstraction and generalization typical of computational thinking.

- It is a logic that allows transition between natural language and the languages of mathematics (Set theory), electronic design (logic gates) and computer programming (TFL+).
- Its multidisciplinary nature makes it an irreplaceable methodological instrument for adaptability and interdisciplinary requirements.

Fred Sommers' Logic. Known as *Term Functor Logic* (TFL) [18,19,29], the system developed by Sommers and Englebretsen is a formal logical language easily assimilated into natural language. Among its advantages we can list:

- Based on the idea that natural language is the "genuine source of natural logic", TFL represents the categorical propositions using an arithmetic grammar (plus-minus algebra).
- Its algebraic representation t this plus-minus algebra offers a simple method of decision for syllogistic.
- Its visible "syntactic naturalness" and the simplicity of its reasoning rules, provide intuitively and immediately cognitively relevant information and make it a "logic of reasoning in natural language".
- Its direct usefulness from the point of view of logical programming languages [3]) and, in particular, through the programming language TFLPL+ [8,11].

6 Conclusions

The usual discourse about technological transformation of education suggests promoting computational thinking because it promotes 21st century skills that are fundamental and not necessarily technological. Our proposal, based on the concept of education by competences, consists of promoting the disciplines of the Trivium for four basic reasons:

- Because they directly promote 21st century skills (Sect. 2).
- Because they offer a sound philosophical framework to reflect on the various problems and conflicts that emerge from the transformations that education is undergoing today (Sect. 3 and Subsect. 5.1).
- Because they promote skills in computer thinking, algorithmic thinking and programming (Sect. 4 and Subsect. 5.2).
- Because they offer a solid base of interdisciplinarity from the epistemological unit of key humanistic disciplines (Trivium disciplines) and STEM disciplines (Sect. 1 and Sect. 5).

In short, what the Trivium offers is a compact disciplinary scheme that brings together the key skills of 21st century education and a solid epistemologically ground for an authentically interdisciplinary education that responds to the exposed requirements of smart education.

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