Concepts characterization and competence assessment for Computational Thinking

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Abstract: - Computational Thinking can be considered as a whole where three important parts are associated in order to complete a transversal competence. These parts are the own competences of Computational Thinking, the attitudes or dispositions that are essential dimensions of Computational Thinking and that support it, and the concepts that are used and developed when you work the Computational Thinking. The transversal competence is the own Computational Thinking. But all competences must be measured in some way if we want to apply them properly and obtain conclusions in order to improve the teaching-learning process. In this paper we present Computational Thinking and its three fundamental parts and we discuss some methods to assess all the process.

Key-Words: - Computational Thinking, assessment, education, teaching, learning, transversal competence, concepts.

1 Introduction

Since the last fifteen years, there are several terms that have taken more and more importance in the field of education, such as ICT skills, new technologies and digital competence.

Europe 2020 is a strategy of the European Union (EU) for development and growth in the next decade. In the framework of a changing world the aim is “EU to become an intelligent, sustainable and inclusive economy”. These words define the priorities that have to promote the achievement of high levels of employment, efficiency and social cohesion by 2020 in EU and the member-states. In the field of education, the priorities are in the intelligent growth sector, which means achieving better results in EU in [1]: a) Education (encouraging people to learn and to master their skills) b) Research/innovations (development of new products or services generating growth and employment and promoting social cohesion) c) Digital society (usage of information and communication technologies)

Many of the educational authorities in Europe have redefined their educational aims and curricula and have focused on the successful application of knowledge and skills, as well as on the usage of appropriate teaching methodology for acquiring this knowledge and these skills [2].

In this context, and with the close past of economic crisis of the last years, the countries of the European Union are carrying out numerous actions to, through the universities, promote measures to alleviate the important youth unemployment and promote the professional qualification and specialization of young people. Some of these actions are combining the teaching-learning process of the training center with learning and work in the company. In addition, these actions also extend to the years prior to university (High School and Vocational Training), where increasingly technology is part of the education system.

The secret of being able to integrate technology into preschool classrooms is to see it as any other tool or material to teach specific skills and concepts. The use of technology in schools is supposed to expand, enrich, implement, individualize, differentiate and extend the curriculum.

Higher education, particularly Engineering, must provide not only discipline-specific fundamental knowledge but also competencies and skills now required by the labour market [3], such as generic skills. Not all graduates may have acquired them as these competencies are sometimes not included in university curricula. Many of these abilities belong to the communicative dimension such as: being able to express themselves accurately both in written or spoken form in different languages, to take decisions, to solve conflicts and to work in groups, among others. Students are also required the ability to adapt to permanent changes, and the formation acquired in the university may not be sufficient, thus continuous learning is needed [4]. More and more, the European Union is promoting this type of learning through initiatives like the Lifelong Learning Programmes and the European Qualifications Framework for Lifelong Learning [5].

One of the several approaches that can be used for the implementation of these changes in education is based on instructional principles deriving from constructivism. Savery and Duffy [6] show these principles as follows: 1. Anchor all learning activities to a larger task or problem. 2. Support the learner in developing ownership for the overall problem or task. 3. Design an authentic task. 4. Design the task and the learning environment to reflect the complexity of the environment they should be able to function in at the end of learning. 5. Give the learner ownership of the process used to develop a solution. 6. Design the learning environment to support and challenge the learner's thinking. 7. Encourage testing ideas against alternative views and alternative contexts and 8. Provide opportunity for and support reflection on both the content learned and the learning process. The instructional design principles can lead to a wide variety of learning environments.

On the other hand, it is obvious that innovation is necessary also in education. The Royal Academy of Spanish Language defines innovation as "change or alter something, introducing novelties". That is, innovation is change, and today, they are inevitable. In Education the emergence of tools that can help improve the teaching-learning dichotomy is taking place very rapidly [7].

Carver A. Mead, professor at the California Institute of Technology, said in 2007 that the education we deliver is what we know, we teach the way we know how to think and yet when our students enter the world and build the future, this knowledge changes very fast. In today's world, most of the knowledge we have will be obsolete in 10 years. Still not tell that to our students. In fact, very often, we ask them to learn everything we know and probably will be futile and will only be a fraction of what they need to know, everything has become new.

It's a slight exaggeration but it has a depth of reason. We must consider modify, change, certain aspects of Education. Herbert Simon, Nobel Laureate in Economics 1978, said "The meaning of "know" has moved from being able to remember and repeat information to being able to find it and use it".

2 Digital competence is assumed by governments

Many of the development and learning needs are coupled well with the appropriate use of technology in the classroom, especially exploring, with the manipulation of symbolic representation, using alternative learning styles and adjusting the modalities of each learning that the student can control and adjust to meet your individual needs.

There is also a danger that technology may be used inappropriately in the classroom, but proper and periodic training of teachers can be a way to minimize this danger. You have to have professionals who can select applications, programs and internet sites appropriate for the development of those ages. They should also be taught digital ethics, which is the power to distinguish the right from the wrong in this area, either with social networks, or sending texts and even not copy information from the Internet without citing where it came from.

In this sense, we can speak about digital competence and how we can introduce it in the educational system. But we do not say within the curricula, but within the day-to-day of our class and homework. In 2006, the European Parliament and the Council [8] published a recommendation identifying eight Key Competences for Lifelong Learning: Communication in the Mother Tongue; Communication in Foreign Languages; Mathematical Competence and Basic Competences in Science and Technology; Digital Competence; Learning to Learn; Social and Civic Competences; Entrepreneurship; and Cultural Awareness and Expression.

Four years afterwards, the value of this recommendation is recognized in the Europe 2020 Strategy [9]. But this is not one more competence, but this 2006 recommendation already points to Digital Competence as a fundamental basic skill. Digital Competence is there defined as follows:

“Digital Competence involves the confident and critical use of Information Society Technology (IST) for work, leisure and communication. It is underpinned by basic skills in ICT: the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet.” [8].

So, if we consider that Computer Science and ICT are generally recognized as very important issues at all levels of Education, and if we read that Digital Agenda for Europe [10] includes them as Pillar VII "ICT-enabled benefits for EU society", then we cannot turn our back on this fact and we should modify our systems.

3 Computational Thinking: some characteristics and definitions

It is generally agreed that today's education systems are facing a big threat of not meeting the requirements and necessities for student motivation and engagement, which is why it is important to use, or at least try to use new possibilities and teaching styles to establish innovative educational system for students benefit now and in the near future [11].

Therefore, it would be desirable to find a methodology or a compendium of norms with some specific characteristics. It should cover different aspects of education and learning; in addition, it would be good if this new framework could be applied to any area of knowledge, that is, that could be used in STEM subjects, or in subjects related to Health, and in the subjects of Arts and Literature too. If in addition to all the above, we could be introducing new technologies and the way of thinking that would be needed to implement the concepts in computers or electronic devices, it would be a better option.

According to the publication DigComp 2.0: The Digital Competent Framework for Citizens [12], of the European Commission's science and knowledge service, there are 21 digital competences that all citizens must have at present. Digital competences encompassed in five areas: Information and Data Literacy, Communication and Collaboration, Creation of digital content, Security and, finally, Problem solving.

These 21 digital competences refer to the search for information on Internet, its evaluation and data management. It also refers to interaction with other people, sharing information, participating, collaborating and following rules of conduct. Of course, the creation of digital content, copyright and programming are included. It also emphasizes security and protection in devices, personal data, health and well-being and the environment. And finally, it makes reference to the identification of technological needs and the resolution of any kind of problems.

And this is where we can introduce Computational Thinking. Its main characteristics include: a) Analyzing and logically organizing data. b) Data modelling, data abstractions, and simulations. c) Formulating problems such that computers may assist d) Identifying, testing, and implementing possible solutions. e) Automating solutions via algorithmic thinking. f)Generalizing and applying this process to other problems.

Computational Thinking is a type of analytical thinking that employs mathematical and engineering thinking to understand and solve complex problems within the constraints of the real world [13]. This term was first used by S. Papert [14] in 1996, who is widely known for the development of the Logo software. However, it was brought to the forefront of the computer society by Wing [15] to describe how to think like a computer scientist. She described CT as "solving problems, designing systems and understanding human behavior by drawing on the concepts fundamental to computer science".

Other recent authors, as Dagienė and Stupuriene, remark that the abilities that computational thinking can provide are really valuable not only for informatics professionals or for students of STEM subjects, but for all citizens [16]. Computational thinking is fundamental to deal with many types of problems, although obviously the first impression is more related to mathematics, science and engineering, where models, simulation and experiments are basic in their learning and are used continuously.

Liu and Wang defined computational thinking as a hybrid of other modes of thinking, like abstract thinking, logical thinking, modeling thinking, and constructive thinking [17]. In this way, they include the main characteristics of CT. For example, abstract thinking is essential in computer science and technology. Logical thinking is the process in which one uses reasoning consistency to come to a conclusion. Modeling thinking, in the technical use of the term, refers to the translation of objects or phenomena from the real world into mathematical equations (mathematical models) or computer relations (simulation models).

Constructive thinking is any well-defined computational procedure that takes some value, or set of values as input and produces some value, or set of values as output.

4 Different types of assessments for different practices

Teaching methods should adapt to the needs of society and students, and nowadays most of them are doing it. Therefore, evaluation methods should also progress in the same direction. Because the traditional teaching methods are based on the theory, the evaluation is normally based on the specific knowledge of the theory, which have the student. Regarding evaluation of different methods, for example in active methodologies, it has a different shape at the time of evaluating the contents.

A characteristic feature of these methods is the absence of a single correct answer (although there are more and less appropriate responses) because the really important is the process which is followed by the students to reach a solution [2].

For this reason, the most important aspects at the time of evaluate are the following: a) The student's reasoning skills b) The relationships that the students established between the different concepts and theories c) The modifications introduced in the way of conceiving knowledge by working with peers.

Continuous assessment takes also a great importance and it has the advantage that it assesses the learning process of students by means of constantly monitoring the work they perform and the knowledge they are acquiring. It means that teacher or student can immediately introduce the necessary modifications to improve the process and get better results.

The evaluation criteria has to be made clear to students developing the activity so that they are aware, or they should be, at all times, always knowing which parameters are to be taken into consideration [18].

In this way, in the current European context, with a severe crisis spread over almost all countries, the innovation competence has become one of the most important issues to be competitive and sustainable. Focus on new assessment procedures is needed, as well as adequate strategies for knowledge acquisition, these being a learning tool to aim at formative assessment. Students and lecturers must be involved in both the learning process and its further analysis.

Among alternative assessment procedures we can find co-assessment [19], [20], [21], which turns out to be a shared responsibility in the evaluation of the learning processes where teacher assessment, self-assessment and peer assessment are included.

Our challenge as teachers is to design or adapt new patterns to perform the assessment and with a high degree of satisfaction of students with the methodology.

A meta-analysis performed by Johnson, Johnson & Stanne [22] shows that higher cognitive outcomes may be reached and students develop a greater motivation, too in [23], [24].

According to Lemke [25], academic goals must match the students' interests and it is a fact that assessment procedures which are perceived as inappropriate lead to a superficial learning. Struyven et al. [26] and Andreu-Andrés [20] think that students' perception about assessment is a very valuable point of view to understand how they learn, and their proposals may provide us with the tool to get the best from them.

Segers and Dochy [27] worked on what students feel about peer assessment and project based learning and how these procedures favour critical thinking and better learning. Hanrahan and Isaacs [28] defined a number of dimensions in a qualitative analysis, which had to be considered in the assessment of individual work. Another relevant study has been carried out by Mc Laughlin and Simpson [29] about peer assessment in first year students who used project based learning, showing a motivating attitude towards this procedure and even high level of thankfulness to their peers for their work. Finally, we can mention Gatfield [30], who did a research about peer assessment to measure individual participation in all group members except for each individual making his own assessment. He used a Likert scale and the results were favourable as regards understanding the process, using appropriate methodology, fairness in the assessment process, etc.

The literature reviewed has shown that the variety in the students' perception to this type of assessment procedures is enormous and this makes it very difficult to identify the right characteristics a procedure like this should have.

5 The Problem of assessing the implementation of Computational Thinking

The Computing Progression Pathways is an example of a non-statutory assessment framework [31]. It was produced by a small team of authors and reviewers, all teachers, based on their classroom experiences. It is an interpretation of the breadth and depth of the content in the 2014 national curriculum for computing program of study.

The key to developing a framework lies in understanding that computational thinking concepts can be demonstrated in multiple ways and because it can be applied for multiple matters, subjects or areas.

Final aim is to assess the implementation of CT in school. Therefore, we follow three different but inter-connected groups of assessments: CT competences, attitudes and used definitions (vocabulary). In any body of a task we can link some part of the body with CT characteristics and measure them.

The competences of the CT that we apply are the following:

- Formulating problems in a way that enables us to use a computer and other tools to help solve them.
- Logically organizing and analyzing data.
- Representing data through abstractions such as models and simulations.
- Automating solutions through algorithmic thinking (a series of ordered steps).
- Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources.
- Generalizing and transferring this problem-solving process to a wide variety of problems.

These competences are supported and enhanced by a number of dispositions or attitudes that are essential dimensions of CT. These dispositions or attitudes include:

- Confidence in dealing with complexity.
- Persistence in working with difficult problems.
- Tolerance for ambiguity.
- The ability to deal with open-ended problems.
- The ability to communicate and work with others to achieve a common goal or solution.

Vocabulary (and definitions) of the CT that can be used in a task:

- Data Collection: the process of gathering appropriate information.
- Data Analysis: Making sense of data, finding patterns, and drawing conclusions.
- Data Representation: Depicting and organizing data in appropriate graphs, charts, words, or images.
- Problem Decomposition: Breaking down tasks into smaller, manageable parts.
- Abstraction: Reducing complexity to define main idea.
- Algorithms and Procedures: Series of ordered steps taken to solve a problem or achieve some end.
- Automation: Having computers or machines do repetitive or tedious tasks.
- Simulation: Representation or model of a process. Simulation also involves running experiments using models.
- Parallelization: Organize resources to simultaneously carry out tasks to reach a common goal.

As a simple but clear example, imagine that we ask our students to do the next task [13]:

We draw a rectangle in a squared sheet. Our rectangle contains inside several small squares (of the squared sheet). Deduce how the area of the rectangle is calculated based on the lengths of the base and height and express it through a single formula.

Solution is obvious: Base x Height. Relation of the body of the task and CT is shown in Table 1.

We use for evaluation of these three inter-connected groups (competences, attitudes and concepts) a model based on rubrics, where teacher must fill in a table, with marks, following a list of questions that lead teacher to assess the three groups of the CT.

Other authors, as Brennan and Resnick [32], articulate their framework for computational thinking in the next three areas: concepts, practices, and perspectives. They define three approaches to assessing the development of computational thinking in young people who are engaging in design activities with Scratch: project portfolio analysis, artifact-based interview approach, and design scenarios.

Table 1. Example of competences, attitudes and concepts.

CT competences	*CT attitudes*	*CT concepts*
"Based on the lengths of the base and height"		
- *Logically organizing and analysing data*	- ***Confidence in dealing with complexity***	- Data analysis - ***Data representation***
"Deduce how the area is calculated"		
- *Representing data through abstractions such as models and simulations*	- ***The ability to deal with open-ended problems***	- Abstraction
"Express it through a single formula"		
- *Formulating problems in a way that enables us to use a computer and other tools to help solve them*	- ***Tolerance for ambiguity***	- Algorithms *and procedures* - Automation

Project portfolio analysis, where each member of the Scratch online community has a profile page that displays their creations, as well as other dimensions of participation, such as projects they have favorited and Scratchers they follow. Teacher analyzes the portfolio of projects uploaded by a particular community member (student).

The second approach to assessing the development of computational thinking is an artifact-based interview approach, that is, interview Scratchers.

Design scenarios is the third approach to assessment. These design scenarios are used exclusively in classroom settings.

These three approaches are focused on the development of computational thinking through Scratch programming activities, so perhaps they cannot be generalized for any type of implementation of computational thinking.

6 Conclusion

Graduates must acquire competences and skills that some years ago did not exist. The change speed in technology is very fast in the last years and the spread of new devices using computational and electronics technologies has reached to the majority of fields, education included. Currently, the great change in the education system has to do with its adaptation to the digital age and its transformation to adapt the students who prepare for a life in which technology is everywhere. In addition, we must also take into account that the labor market is constantly evolving, and that in the near future there will be professions that we cannot even imagine now.

From the institutions, a great effort is being made and the digital competence has been talked about for a few years now. But also from the educational sectors are promoting new ideas so that the adaptation to this new era is faster and better. In this sense, computational thinking has emerged with strength and is making its way around the world.

In some way, computational thinking include digital competence, so we need to define firstly computational thinking. It is a type of analytical thinking that employs mathematical and engineering thinking in order to understand and solve complex problems within the constraints of the real world.

After the own definition, we have to define the methodology and type of assessment. We cannot forget that any system or methodology that we use should be possible to measure it. One starting point for this is to see how much it is fulfilled, and if what we expect has been implemented or not. That is why the computational thinking assessment is an important part of its implementation. The assessment presented in this paper is not intended to be the only one valid for its purpose, but at least a starting point in the evaluation of the implementation of computational thinking.

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