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A common model for tracking student learning and knowledge acquisition in different e-Learning platforms

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Abstract

E-Learning environment implies self-motivation and perseverance in study and completion of learning tasks. However, the more autonomy students have in managing their e-Learning, the harder they cope with distractions and remaining focused and engaged. This research study aims to assess the level of student engagement in four e-Learning platforms (CoLaB Tutor, AC-ware Tutor, CM Tutor and Moodle) in higher education. A model for Tracking Student Learning and Knowledge (TSLAK) is developed and based on two sets of variables: variables tracking student's learning activities (VTL) and variables tracking student's knowledge (VTK). This study aims to provide answers on how a model for tracking student online learning and knowledge can be formalized for the four e-Learning platforms and how can student learning and knowledge acquisition processes be described and measured by VTL and VTK. The results obtained by VTL and VTK indicate a significant decline in students' engagement. Out of 218 the most engaged students, 77 (35%) of them used the CoLaB Tutor, 41 (19%) used the AC-ware Tutor, 52 (24%) used the CM Tutor, and 48 (22%) used the Moodle. The research showed that out of the total number of students only 88 (13%) of them were the most engaged and the most successful or more precisely, 63 (71%) graduates and 25 (29%) undergraduates. Such student engagement and success measured by VTL and VTK indicate the necessity of increasing students' motivation in blended learning environments, strengthening their preparation and introduction to e-Learning platforms, and observing their feedback during a research study.

KEYWORDS: Distributed Learning Environments, Evaluation of CAL Systems, Intelligent Tutoring Systems

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1. Introduction

Today, e-Learning encompasses a wide range of methods for computer-assisted knowledge acquisition. E-Learning means knowledge and skill development supported by the use of information and communication technology which makes the world of education more challenging. Effective e-Learning requires a well-planned and structured learning environment, but also students' motivation and engagement. E-Learning

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systems are increasingly useful and popular within the academic community and industry because of flexibility in time, place (access from any location) and pace of learning. Online courses are reforming formal education, not only because of their delivery to desktop, laptop, tablet, or smartphone, but students feel more familiar and comfortable with using the Internet. Proponents of the more traditional (face-to-face) method of teaching and learning often stick to their beliefs that the role of teachers is irreplaceable, whereas their counterparts claim that online learning is a much more efficient method. Certainly, e-Learning not only provides a huge amount of knowledge and information but enables interaction, direction, and timely feedback. If combined with traditional learning to supplement and improve the learning process it can be defined as blended learning.

In the context of educational software, online or blended courses are now globally held on two types of e-Learning platforms, Learning Management Systems (LMSs) and Intelligent Tutoring Systems (ITSs).

Learning management systems are defined by Kats (2010) as full-scale learning platforms supporting multiple features of an educational process, from administrative functions to course delivery and assessment. LMSs centralize and automate administration; provide use of self-service and self-guided services; assemble and deliver learning content; consolidate learning initiatives on a scalable web-based platform; support portability and standards; personalize content and enable the reuse of knowledge.

Intelligent tutoring systems are computer systems that provide immediate and personalized instruction or feedback to students, usually without intervention from a human tutor (Psotka et al., 1988). The pedagogical framework of e-Learning has evolved from computer-assisted instruction grounded in behavioral learning theory to cognitive learning theory and teaching paradigm. The intelligent tutoring draws its characteristics and strengths from different disciplines that lie at the intersection of computer science, cognitive psychology and educational research (Kearsley, 1987); this field is often referred to as cognitive science. ITSs take into account the knowledge about what to teach (the subject matter), the way to teach (the learning and teaching scenario), as well as the relevant information about the student being taught (Rosic et al., 2005). With respect to the pedagogical paradigm, ITSs represent the best way to enable one-to-one instruction (Fletcher, 2003) and at the same time the best effort in solving the '2-sigma problem', as pointed out in Bloom's comparison of traditional teacher-centered class vs. individualized instruction (Bloom, 1984).

In the e-Learning environment, much pressure is put on teachers who strive to design an online-course that increases students' motivation and provides active learning and personalized feedback. The learning outcomes include a number of indicators associated with the learning and teaching processes as well as student achievement. Learning Analytics (LA) deployed in educational settings makes student's activity more accurately reflected in the analysis (Baker & Siemens, 2013). The collected data sets result from the learning, teaching and testing processes including e.g. the amount of time spent on the online course, the knowledge presented as course elements and concepts of domain knowledge and knowledge evaluation expressed through learning outcomes. Student engagement is concerned with the interaction between the time, effort and other relevant resources invested by both students and their institutions intended to optimise the student experience and enhance the learning outcomes and development of students and the performance, and reputation of the institution (Trowler, 2010).

This research aims to assess student engagement in using different e-Learning platforms in higher education. We conducted the research study in a blended learning environment with the rotation model and the flipped classroom as a sub-model (Staker & Horn, 2012). These e-Learning environments represent a unique space in which student engagement is measured by learning analytics. Two sets of variables are introduced: variables tracking student's learning activities (VTL) and variables tracking student's knowledge (VTK). VTL are used to track whether students learned online, completed the online course and took the written tests. VTK are used to track the number of lessons, the number of objects, score gained, time spent online, and results gained in pre - and post-tests. This study aims to provide answers to the following questions:

- How can a model for tracking student online learning and knowledge acquisition be formalized for the four different e-Learning platforms?
- How can student engagement be described and measured by VTL and VTK during the learning, teaching and testing processes in the online course?

The next two sections provide a literature review followed up by our research achievement so far. The fourth section focuses on the methodology i.e. Model for Tracking Student Learning and Knowledge (TSLAK), whereas the section referring to results and discussion provide data analysis and interpretation, statistics and arguments supported by evidence. Key findings, research contribution and suggestions for future research are highlighted in the conclusion.

2. Literature Review

Kuh (2009) defined student engagement as the participation in educationally effective practices, both inside and outside the classroom, with emphasis that active engagement leads to a range of measurable positive outcomes. Krause and Coates (2008) defined it as the extent to which students are engaging in activities that higher education research has shown to be linked to high-quality learning outcomes. In general, student engagement is more than involvement or participation – it requires feelings and sense-making along with student activity (Harper & Quaye, 2008; Trowler, 2010).

Referring to Bloom's taxonomy of educational objectives (Bloom, 1956), Fredricks, Blumenfeld, & Paris (2004) identified three dimensions of student engagement: (i) behavioral engagement, (ii) emotional engagement, and (iii) cognitive engagement. Students who are behaviorally engaged would typically comply with behavioral norms, such as attendance and involvement, and would demonstrate the absence of disruptive or negative behavior. Students who engage emotionally would experience affective reactions such as interest, enjoyment, or a sense of belonging. Cognitively engaged students would be invested in their learning, would seek to go beyond the requirements, and would relish the challenge. This research focuses on behavioral aspect of student engagement, which is considered crucial for achieving preferable academic outcomes.

As for the use of LA to examine student behavior in an online learning environment, researchers tracked different types of data in order to measure students' participation and login frequencies; time spent on answering questions and solving tasks; resources accessed; number of questions and chat messages exchanged between participants, previous and final grades in courses, detailed profiles, LMS preferences, forum and discussion posts, affect observations, etc.

There are several research studies that measure students' performance in courses, the results of initial test, or assignments during the study (Huang & Fang, 2013; Lykourentzou et al., 2009); students' behavior regarding single online activity (i.e. login frequency) and collaborative online activities (i.e. the number of forum posts read) (Abdous et al., 2012; Falakmasir & Habibi, 2010; Lin & Chiu, 2013; Macfadyen & Dawson, 2010; Morris et al., 2005; Romero et al., 2012; Romero-Zaldivar et al., 2012; Shih et al., 2010; Smith et al., 2012); students' affective states while learning online (Moridis & Economides, 2009; Z.A. Pardos et al., 2014); an overview of the existing and other approaches (Dietz-Uhler & Hurn, 2013; Kotsiantis et al., 2013; Liu et al., 2009; Minaei-Bidgoli et al., 2003; Wang & Newlin, 2000). These tracking variables are used for different research objectives, from the prediction of students' performance to the description of students' behavior and engagement. To the best of our knowledge, there is no single use of specific tracking variables to describe student engagement in online learning.

Taking into account the above-mentioned researches and variables, we introduced two sets of tracking variables (VTL and VTK) that are typical to different e-Learning platforms and domain knowledge acquisition.

3. Research Context

We have focused our interests on the research, development, and application of e-Learning platforms in the online and blended learning environment since 2003. It resulted in the teacher-student communication in controlled natural language and the Controlled Language-Based Tutor (CoLaB Tutor) for the Croatian language (Žitko, 2010), followed up by the Adaptive Courseware Tutor Model - AC-ware Tutor (Grubišić, 2012), which takes into account the current level of students' knowledge and their cognitive characteristics that determine the complexity and level of the used course elements. Finally, the Content Modelling Tutor – CM Tutor (Volarić, 2017) refers to the personalized knowledge acquisition through the use of concept maps, multi-criteria decision-making methods, mathematical methods and stereotype-based student modeling. These e-Learning platforms, Tutors, share common processes: (i) domain knowledge design, (ii) learning and teaching, (iii) testing, and (iv) student modeling, as described below.

3.1. Domain Knowledge Design

Designing domain knowledge in the CoLab Tutor, the expert uses the Protégé OWL Plugin, (Knublauch et al., 2004) to develop ontology in the Web Ontology Language (OWL) (Bechhofer et al., 2004). This ontology is the main dataset for the later phases. The OWL is then transformed into domain knowledge and deployed in the CoLaB Tutor. Afterwards, the course elements and the initial student model are automatically created from the domain knowledge. Domain knowledge is a static and unchangeable structure.

Domain knowledge design in the AC-ware Tutor is based on the third-party concept map editor - CmapTools (Novak & Cañas, 2006). This concept map is transformed into domain knowledge and deployed in the AC-ware Tutor. Afterwards, an initial set of course elements is automatically generated from the domain knowledge. Domain knowledge is a static and unchangeable dataset.

Domain knowledge design in the CM Tutor is also based on concept maps and generated the same way as in the AC-ware Tutor; it remains static and unchangeable.

All the Tutors use concept maps (Novak & Cañas, 2008), which highlight relationships between different concepts. Figure 1 illustrates a domain knowledge formalized through graphic representation. They are used for domain knowledge visualization and classification, a course design, teaching and learning, decision making, problem-solving. They can be supplemented by hypermedia (images, textual formats, animated formats, URL addresses, etc.).

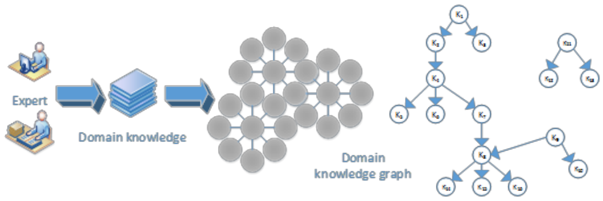

Figure 1 - From concept map to domain knowledge graph

The formalism for designing domain knowledge is unique and valid for all Tutors. In that sense, the set $K=\{k\_1,k\_2,k\_3, \dots ,k\_n\}$, $n>=0$ includes a set of concepts and a set of relations $R=\{r\_1,r\_2,r\_3,\dots,r\_m\}$, $m\geq 0$. Each ordered triplet $⟦P\_l=(k⟧\_i,k\_k,r\_j)|k\_i\in K,k\_k\in K,r\_j\in R,1\leq i\leq n,1\leq k\leq n,1\leq j\leq m,i\neq k$ represents a proposition and a set of all propositions $D\_k=\{P\_1,P\_2,P\_3, \dots ,P\_l\}$ is called domain knowledge. In this structure, concepts k1 and k2 are associated with relation rj. This way, we define that the concept k1 is the super concept of concept k2, and that the concept k2 is the sub-concept of the concept k1. Additionally, if domain knowledge includes the set of hypermedia attributes $H=\{h\_1,h\_2,\dots,h\_o\}$, $o>=0$, then each ordered pair $N=\{(k\_i,h\_j)\,|\,k\_i\in K,h\_j \in H,1\leq i\leq n,1\leq j\leq o\}\subset K\times H$ is called a structural attribute of a given concept.

3.2. Learning and Teaching

In the CoLab Tutor, course elements are static structures whose order and context are unchangeable during learning, teaching and testing phases, during which a dictionary containing all domain knowledge concepts and relation names is deployed. These names are either single words or multiword expressions. As for the dictionary deployment, two services are involved: the Controlled Language Service (CoLaS) for recognizing phrases and the Croatian Morphological Lexicon (CML) for word recognition (Tadić & Fulgosi, 2003). Course elements are presented in a controlled natural language and are supplemented with the elements of hypermedia (Figure 2).

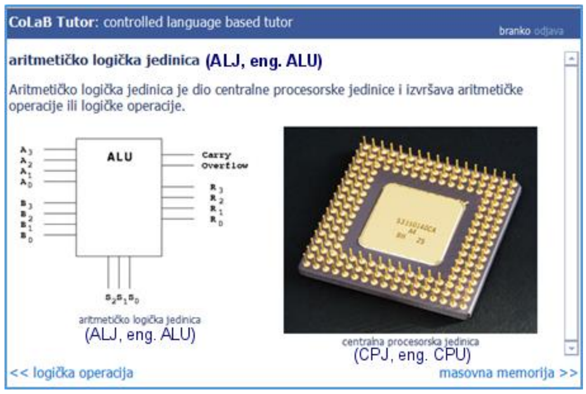

Figure 2 - CoLaB Tutor learning and teaching

The AC-ware Tutor is based on automatic and dynamic generation, adaptive selection, sequencing, and presentation of course elements. It takes into account the current level of student's knowledge that determines the complexity and the level of presented course elements. The automatic course elements generation designates that the course elements are created by the system itself (not by the human teacher). The dynamic generation indicates that the course element is created in the moment of execution. Adaptive selection, sequencing, and presentation of course elements are done automatically and dynamically in accordance with a student model using sentence and questionnaire templates. The course element presentation using sentence template is presented in Figure 3.

In CM Tutor, learning and teaching are done through visualization tools such as a concept map based on hypermedia environment. In this phase, domain knowledge is presented as a whole, i.e. it is not divided into course elements (Figure 4).

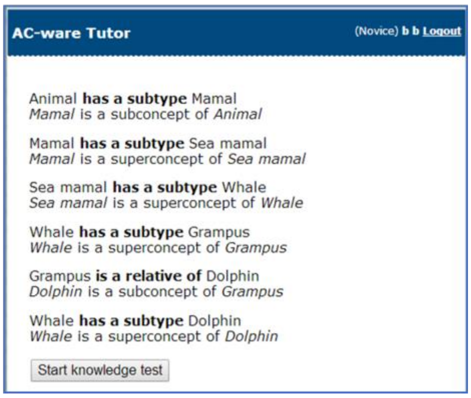

Figure 3 - AC-ware Tutor learning and teaching.

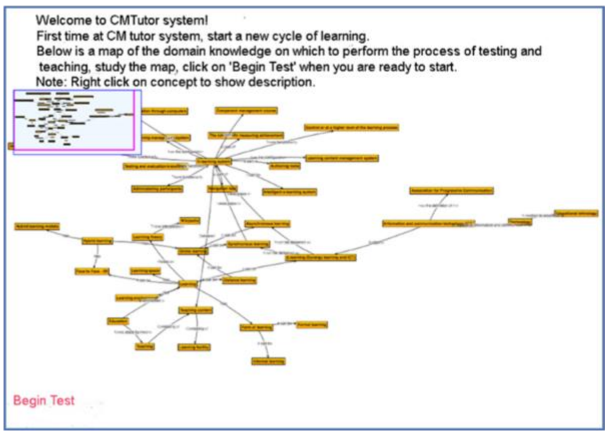

Figure 4 - CM Tutor learning and teaching.

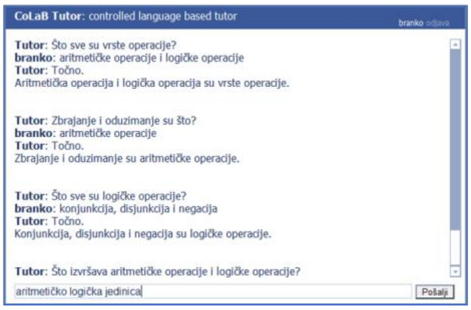

Figure 5 - Tutorial dialogue in CoLab Tutor.

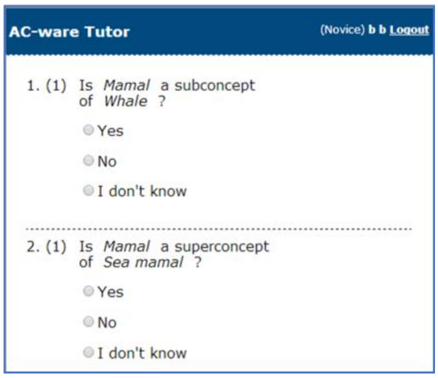

Figure 6 - AC-ware Tutor testing.

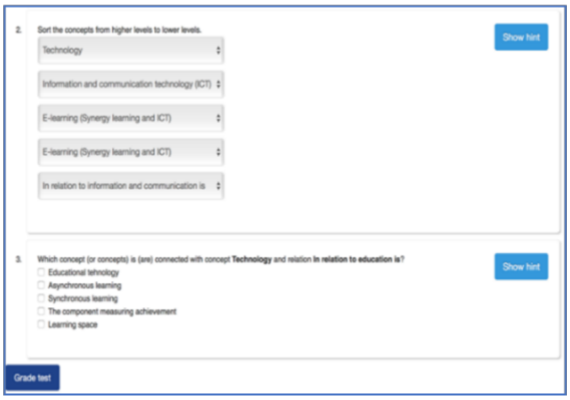

Figure 7 - CM tutor testing.

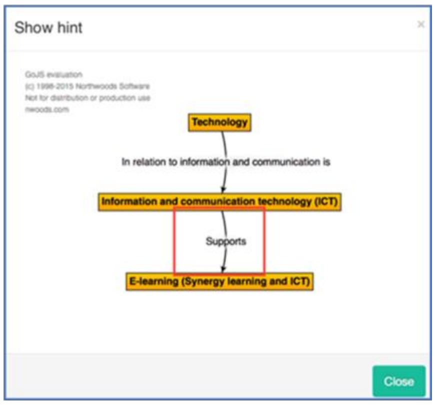

Figure 8 - CM tutor help.

3.3. Testing

Testing in the CoLab Tutor encompasses the process of reasoning about domain knowledge, student modeling, and the controlled natural language processing. Communication between the CoLaB Tutor and the student is carried out using controlled language, so the CoLaS, supported by the CML, is a provider for the controlled language generation and recognition. Testing is performed by tutorial dialogue (Figure 5), in which testing elements are presented as a sequence of dialogue patterns (Graesser et al., 1995). The Tutor's questions in dialogue result from the controlled language generation over domain knowledge, while student's answers are analyzed using controlled language recognition.

In the AC-ware Tutor, questions and adaptive tests are automatically and dynamically generated for an individual student and therefore are not repetitive. In this way, a common problem related to computer-assisted testing, which requires many pre-written teacher's questions with different difficulty levels, is resolved. An example of a questionnaire template used for knowledge testing is presented in Figure 6.

In the CM Tutor, the testing process includes the automatic generation of a series of questions required to assess students' current knowledge. Each test consists of questions related to the unlearned concepts (Figure 7). If they have a problem with any question, students can ask for help, which is provided by a system in the form of a mini concept map corresponding to that particular question (Figure 8).

3.4. Student Modelling

Student model in the CoLaB Tutor uses the overlay model. The course contains the sequence of course elements each mapped individually to some subset of domain knowledge.

Student model in the AC-ware Tutor is based on stereotypes defined according to the Bloom's knowledge taxonomy (Bloom, 1956) and on Bayesian networks used to predict knowledge (Zachary A. Pardos & Heffernan, 2010), as described specifically in the work of Grubišić et al. (2013).

Student modelling in the CM Tutor is performed by using the Fuzzy Analytic Hierarchy Process (FAHP) (Chang, 1996) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Hwang & Yoon, 1981).

Encouraged by the results obtained in studies carried out from primary education to higher education (Grubišić et al., 2013, 2014, 2016), we started to develop new e-Learning platform upgrading it with fundamental features such as natural language processing and adaptivity (www.acnltutor.net/). The first phase of this research and development project is focused on observing students' use the Tutors (CoLaB Tutor, AC-ware Tutor, CM Tutor) and Moodle platform (www.moodle.org). Several studies were conducted in order to assess student engagement in online courses using tracking variables and learning analytics. Model for Tracking Student Learning and Knowledge (TSLAK) was used to track student engagement in online learning, teaching and testing processes, as described in the next chapter.

Since domain knowledge and learning analytics are interrelated, two sets of variables were used to observe and track student engagement in the experimental e-Learning platforms which have different functionalities, but common domain knowledge structure and instructional design. Therefore, learning analytics is deployed to assess students' engagement based on variables tracking students' learning activities (VTL) and variables tracking students' knowledge (VTK) gained in the online course.

4. Methodology

The research study was conducted at the Faculty of Science and the Faculty of Philosophy, the University of Split, Croatia and the Faculty of Science and Education, the University of Mostar, Bosnia and Herzegovina and involved 649 undergraduate and graduate students; precisely 238 graduates (36,67%) and 411 undergraduates (63,33%) as shown in Table 1. The three types of domain knowledge (DK) used in the research study were: "Computer as a system" (DK1), "E-Learning systems" (DK2) and "Introduction to Programming" (DK3) and the research study lasted two months. Students were informed about the research topic and motivation, research objectives, research methodology and a time schedule.

Students were engaged in three study cycles, each one lasting for two weeks. At the beginning of each cycle, students were required to write pre-test and upon the completion of each cycle (at least 2h per week) students wrote post-test. Students were divided into 4 groups, and in each study cycle, each group acquired different domain knowledge and used different e-Learning platform.

The aim of the research study was to track students' engagement and domain knowledge acquisition in the four e-Learning platforms. Therefore, a model for Tracking Student Learning and Knowledge (TSLAK) was used to provide deep insight into student engagement and to reconstruct the online learning process using two sets of tracking variables (i) variables tracking student's learning activities (VTL) and (ii) variables tracking student's knowledge (VTK) (as shown in Tables 2 and 3).

Since this study was conducted in the blended learning environment, we could expect that some students would not presumably use e-Learning platforms at all. Therefore, variables tracking student learning were used to determine whether or not students learned online, i.e. variables indicating students' learning online (LO) or non-learning online (NLO). Students who learned online produced online learning records (OLR). In this way, we could determine whether or not students passed all course elements, i.e. variables tracking online course completion (OCC) and online course non-completion (OCNC). Also, the summative assessment method such as the paper-based pre- and post-testing (P&PT) and non-pre- and/or post-testing (NP &/or NPT) were used to observe student engagement in learning. Variables tracking students' knowledge were used to track (i) the number of course elements, i.e. variable tracking number of lessons (NL) and number of objects (NO); (ii) variable tracking score gained in each e-Learning platform (S); (iii) a total time spent online (TSO), and variables tracking results gained in pre - and post-tests (Pre-TR and Post-TR).

The TSLAK structure as shown in Figure 9 involve: (i) a student engaged in learning, teaching and knowledge testing and (ii) the teacher who designs and delivers the course content and sets up the teaching strategies. The

E-Learning platforms	Domain knowledge and number of students		
	DK1 – # Students	**DK2 – #Students**	**DK3 – #Students**
CoLab Tutor	55 – graduates	43 - undergraduates	62 - undergraduates
AC-ware Tutor	41 - undergraduates	42 - graduates	69 - undergraduates
CM Tutor	42 - graduates	70 - undergraduates	57 - graduates
Moodle	64 - undergraduates	62 - undergraduates	42 - graduates
Total no. graduates	97	42	99
Total no. undergraduates	105	175	131
Total	202	217	230

Table 1 - E-Learning platforms and the number of students.

Variables tracking learning (VTL)		
Acronym	**Name**	**Description**
LO	Learning online	True if student logged into the system at least once
NLO	Non-learning online	True if the student had no online learning records
OLR	Online learning records	System logs
OCC	Online course completion	True if the student completed the online course
OCNC	Online course non-completion	True if the student did not complete the online course
P&PT	Pre- and post-testing	True if the student wrote both pre- and post-tests
NP&/or NPT	Non-pre- and/or non-post-testing	True if the student did not write both pre- and post-tests

Table 2 - Variables used to track learning.

Variables tracking knowledge (VTK)		
NL	Number of lessons	Numerical value
NO	Number of objects	Numerical value
S	Score	Numerical value
TSO	Time spent online	Numerical value (minutes)
Pre-TR	Pre-test result	Numerical value (0-100 points)
Post-TR	Post-test result	Numerical value (0-100 points)

Table 3 - Variables used to track knowledge.

process of learning is developed by the teacher who decides on instructional design and teaching strategies (phases 1 and 2). The student learns course materials (phase 3), and the flow of all activities is recorded in the knowledge database (phase 4). During the process of online learning in experimental platforms and upon its completion, the teacher runs SQL query over database tables. The data extracted in tables (phase 5) were used for further analysis and processing based on learning analytics (phase 6). The teacher assesses students' progress (phase 7) and this progress assessment serves as the basis for a new cycle of online learning (phase 8).

For the real-time tracking and visualization of student engagement, e.g. in CM Tutor, as shown in Figure 10, a learning analytics dashboard is used. It displays information about a student's learning and progress through variables tracking: number of concepts (1), score (2), and time spent in online learning (3a) and (3b). This external visualization and internal mechanisms of learning analytics help improve teaching quality and student engagement in online learning.

5. Results and Discussion

Student engagement in online learning, teaching and testing processes was observed and evaluated through variables tracking students' learning (VTL) and variables tracking students' knowledge (VTK). In the case of VTL, students differed with respect to whether they were learning online, whether they took both paper-based tests, and whether they completed the online

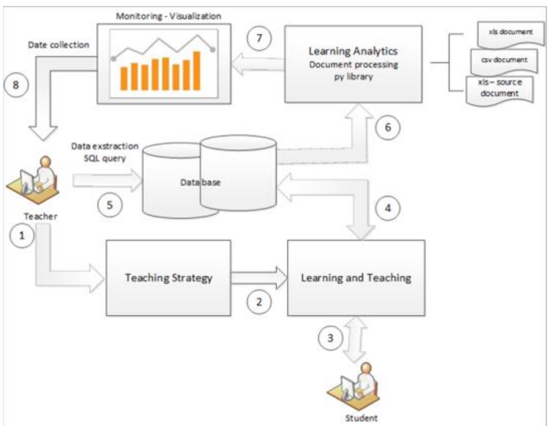

Figure 9 - The TSLAK structure.

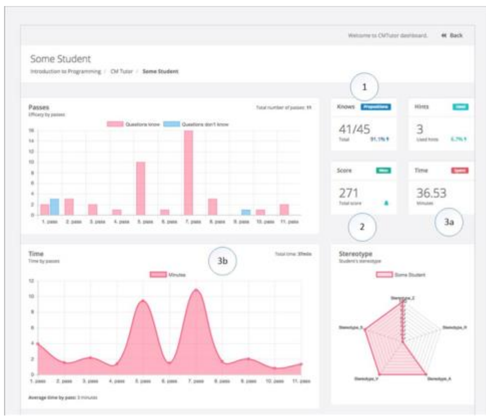

Figure 10 - Dashboard for CM Tutor.

course. The number of students per each e-Learning platform and VTL is shown in Table 4. Out of 649 students, 480 (74%) of them learned online, whereas 169 (26%) students did not learn. Out of those who learned online, 380 (79%) of them wrote and 100 (21%) of them did not write pre-test and/or post-test. Out of those who learned online and took pre- and post-test, 218 (57%) of them completed the course, and 162 (43%) students did not. Out of 218 the most engaged students, 77 (35%) of them used the CoLaB Tutor, 41 (19%) used the AC-ware Tutor, 52 (24%) used the CM Tutor, and 48 (22%) used the Moodle. Out of 160 students using CoLaB Tutor, 77 (48%) of them were engaged in relation to those who neither learned online; nor took both tests and/or completed the online course, as measured by VTL. Out of 152 students using the AC-ware Tutor, there were 41 (27%) the most engaged student. VTL showed that out of 169 students using CM Tutor, 52 (30%) of them were the most engaged. There were 48 (29%) the most engaged students out of 168 who used Moodle. A gradual decline in the number of students indicates that a lack of student engagement and perseverance had a negative impact on their performance.

In addition to the number of engaged students per each e-Learning platform, Table 5 shows the number of graduates and undergraduates according to the engagement measured by VTL. There were 72 (33%) graduates and 146 (67%) undergraduates out of 218 the most engaged students. Out of all 480 graduates who learned online, only 72 (15%) of them were engaged, as measured by VTL. Out of 284 undergraduates who learned online, 146 (51%) of them wrote both paper-based tests and completed the online course. Graduate students were obviously less motivated to learn online and acquire knowledge than undergraduate students.

In further analysis, we observed 218 the most engaged students using VTL. Since those students completed online learning and took pre- and post-tests, we analyzed their success using VTK.

Tables 6-9 provide descriptive statistics of VTK for the four e-Learning platforms. The post-test results were divided into two groups: the results less than 50% (Post-TR<50%), and the results greater than or equal to 50% (Post-TR≥50%). For groups of students whose post-test results were not greater than or equal to 50%, and a standard deviation could not be calculated, there were no data (nd). The mean value, the minimum and maximum values, and the standard deviation were calculated for each VTK, e-Learning platform and domain knowledge.

Although it was expected that the more time students spent in each e-Learning platform, the better would be their post-test results, the study showed rather opposite results. Out of three groups (G1-G9) of students that used ITSs as e-Learning platforms, there was at least one group (G2, G4, G8, G9) per each platform that had positive post-test results (Post-TR≥50%) despite the less time they spent in e-Learning platforms. As for the two groups (G10, G11) of students that used Moodle, their time spent online corresponded to their success and the post-test results.

It is to point out that some groups of students did not obtain post-test results greater than or equal to 50%. There were two groups of students (G3, G6), that had no student who got a positive post-test result and only one group (G8) that had one student who had a positive post-test result. There was one AC-ware group (G5) that had 12 students with a post-test result greater than 50% and no student with negative post-test. Also, there was one Moodle group (G12) that had 4 students with a post-test result greater than 50% and no student with negative post-test.

E-Learning platforms		**LO**					**NLO**	**Total**
		P&PT			**NP &/or NPT**	**Total**	**Total**	
		OCC	**OCNC**	**Total**	**Total**			
CoLaB Tutor	DK1	33	8	41	6	47	8	55
	DK2	29	0	29	5	34	9	43
	DK3	15	11	26	3	29	33	62
	Total	77	19	96	14	110	50	160
AC-ware Tutor	DK1	24	3	27	8	35	6	41
	DK2	12	12	24	8	32	10	42
	DK3	5	27	32	11	43	26	69
	Total	41	42	83	27	110	42	152
CM Tutor	DK1	16	24	40	0	40	2	42
	DK2	29	2	31	20	51	19	70
	DK3	7	19	26	12	38	19	57
	Total	52	45	97	32	129	40	169
Moodle	DK1	25	8	33	20	53	11	64
	DK2	19	13	32	7	39	23	62
	DK3	4	35	39	0	39	3	42
	Total	48	56	104	27	131	37	168
Total		218	162	380	100	480	169	649

Table 4 - Description of student engagement using VTL.

E-Learning platforms		LO					NLO	Total
		P&PT			NP &/or NPT	Total	Total	
		OCC	OCNC	Total	Total			
CoLaB Tutor	DK1	33	8	41	6	47	8	55
	DK2	29	0	29	5	34	9	43
	DK3	15	11	26	3	29	33	62
	Total	77	19	96	14	110	50	160
AC-ware Tutor	DK1	24	3	27	8	35	6	41
	DK2	12	12	24	8	32	10	42
	DK3	5	27	32	11	43	26	69
	Total	41	42	83	27	110	42	152
CM Tutor	DK1	16	24	40	0	40	2	42
	DK2	29	2	31	20	51	19	70
	DK3	7	19	26	12	38	19	57
	Total	52	45	97	32	129	40	169
Moodle	DK1	25	8	33	20	53	11	64
	DK2	19	13	32	7	39	23	62
	DK3	4	35	39	0	39	3	42
	Total	48	56	104	27	131	37	168
Total		218	162	380	100	480	169	649

Table 4 - Description of student engagement using VTL.

	480 students – LO		380 students – LO and P&PT		218 students – LO and P&PT and OCC	
DK	Grad.	Undergrad.	Grad.	Undergrad.	Gradu.	Undergrad.
DK1	87	88	81	60	49	49
DK2	32	124	24	92	12	77
DK3	77	72	65	58	11	20
Total	196	284	170	210	72	146

Table 5 - Description of graduate/undergraduate student engagement using VTL.

		CoLaB Tutor					
		DK1 – G1		DK2 – G2		DK3 – G3	
VTK	Indicator	Post-TR<50	Post-TR≥50	Post-TR<50	Post-TR≥50	Post-TR<50	Post-TR≥50
	#Students	3	30	24	5	15	0
NL	Mean	5	5	5	5	4	nd
	Min	5	5	5	5	4	nd
	Max	5	5	5	5	4	nd
	SD	0	0	0	0	0	nd
NO	Mean	43	43	28	28	44	nd
	Min	43	43	28	28	44	nd
	Max	43	43	28	28	44	nd
	SD	0	0	0	0	0	nd
S	Mean	43.05	41.04	14.14	13.75	46.15	nd
	Min	38.47	28.58	6.45	7.97	33.04	nd
	Max	47.15	50.79	18.02	17.04	51.53	nd
	SD	4.36	6.86	2.97	3.67	5.50	nd
TSO	Mean	75.66	82.96	74.20	72.4	76.93	nd
	Min	50	23	41	34	21	nd
	Max	108	226	113	96	174	nd
	SD	29.56	59.79	24.63	25.65	44.10	nd
Pre-TR	Mean	30.33	38.46	19.85	31.7	21.92	nd
	Min	25	14	0	18	6.3	nd
	Max	38	65	59.5	44	43	nd
	SD	6.80	13.02	14.53	10.82	9.82	nd
Post-TR	Mean	42	70.46	27.60	66.3	17.56	nd
	Min	33	54	6	57.5	0.3	nd
	Max	48	94	48.5	80.5	34.3	nd
	SD	7.93	10.01	12.02	9.52	10.99	nd

Table 6 - Description of student engagement using VTK (CoLaB Tutor).

		AC-ware Tutor					
		DK1 – G4		**DK2 – G5**		**DK3 – G6**	
VTK	**Indicator**	**Post-TR<50**	**Post-TR≥50**	**Post-TR<50**	**Post-TR≥50**	**Post-TR<50**	**Post-TR≥50**
	#Students	12	12	0	12	5	0
NL	**Mean**	15.41	11	nd	3.75	12.6	nd
	Min	5	2	nd	1	1	nd
	Max	37	44	nd	9	40	nd
	SD	10.30	11.51	nd	2.30	16.34	nd
NO	**Mean**	71	71	nd	39	83	nd
	Min	71	71	nd	39	83	nd
	Max	71	71	nd	39	83	nd
	SD	0	0	nd	0	0	nd
S	**Mean**	315.5	333.25	nd	155.5	208.4	nd
	Min	212	241	nd	69	120	nd
	Max	348	348	nd	168	336	nd
	SD	51.02	34.04	nd	28.67	116.50	nd
TSO	**Mean**	129.9	80.28	nd	43.25	64.48	nd
	Min	64.88	27.26	nd	13.31	7.36	nd
	Max	269.55	145.93	nd	82.58	173.36	nd
	SD	53.47	41.89	nd	25.38	67.95	nd
Pre-TR	**Mean**	22.91	30.5	nd	60.25	24.76	nd
	Min	0	11	nd	26	9.8	nd
	Max	41	58	nd	83	45	nd
	SD	11.36	12.53	nd	18.21	12.91	nd
Post-TR	**Mean**	33.33	65.75	nd	86.33	26.06	nd
	Min	12	50	nd	75	16	nd
	Max	48	91	nd	92	42.5	nd
	SD	11.06	11.52	nd	6.05	11	nd

Table 7 - Description of student engagement using VTK (AC-wareTutor).

		CM Tutor					
		DK1 – G7		**DK2 – G8**		**DK3 – G9**	
VTK	**Indicator**	**Post-TR<50**	**Post-TR≥50**	**Post-TR<50**	**Post-TR≥50**	**Post-TR<50**	**Post-TR≥50**
	#Students	2	14	28	1	4	3
NL	**Mean**	27	28.21	53.53	49	71.75	49.33
	Min	23	22	22	49	42	27
	Max	31	36	119	49	137	82
	SD	5.65	4.29	19.09	nd	44.05	28.91
NO	**Mean**	71	71	39	39	111	111
	Min	71	71	39	39	111	111
	Max	71	71	39	39	111	111
	SD	0	0	0	nd	0	0
S	**Mean**	612	672.14	356.5	349	1245	948.16
	Min	548	585	145.5	349	1053	831.5
	Max	676	780	542	349	1518	1072
	SD	90.50	62.25	87.53	nd	213.31	120.41
TSO	**Mean**	91.64	92.70	67.41	62.58	376.65	158.38
	Min	65.65	45.61	18.86	62.58	207.15	124.3
	Max	117.63	143.91	175.03	62.58	738.36	223.2
	SD	36.75	24.42	35.43	nd	243.68	56.15
Pre-TR	**Mean**	28	33.35	24.01	33	17.57	23.5
	Min	21	5	6	33	14	16.5
	Max	35	53	45	33	24.5	35
	SD	9.89	12.98	10.46	nd	4.83	10.03
Post-TR	**Mean**	0	90.42	26.57	52	21.25	55.83
	Min	0	78	9	52	0	50
	Max	0	97	41	52	42	67.5
	SD	0	4.84	8.15	nd	17.95	10.10

Table 8 - Description of student engagement using VTK (CM Tutor).

		Moodle					
		DK1 – G10		DK2 – G11		DK3 – G12	
VTK	Indicator	Post-TR<50	Post-TR≥50	Post-TR<50	Post-TR≥50	Post-TR<50	Post-TR≥50
	#Students	23	2	14	5	0	4
NL	Mean	20	20	5	5	nd	4
	Min	20	20	5	5	nd	4
	Max	20	20	5	5	nd	4
	SD	0	0	0	0	nd	0
NO	Mean	275.52	341	57	67.8	nd	50.5
	Min	232	233	14	46	nd	37
	Max	444	449	159	129	nd	70
	SD	47.26	152.73	34.79	34.85	nd	14.61
S	Mean	82.92	84.02	69.64	89.37	nd	83.33
	Min	64.17	83.04	0	85.42	nd	66.67
	Max	98.33	85	93.75	93.75	nd	100
	SD	8.92	1.38	29.90	3.15	nd	19.24
TSO	Mean	140.30	238	64.07	74.6	nd	37.25
	Min	34	224	7	46	nd	17
	Max	260	252	184	101	nd	71
	SD	58.56	19.79	41.40	22.23	nd	23.97
Pre-TR	Mean	15.91	24	15	26	nd	31
	Min	0	20	6.5	15.5	nd	0
	Max	26	28	26	39.5	nd	50
	SD	6.82	5.65	5.37	8.62	nd	21.69
Post-TR	Mean	23.78	51.5	27.10	53.5	nd	85
	Min	6	51	13	51	nd	55
	Max	45	52	46	56.5	nd	99
	SD	11.42	0.70	10.57	2.64	nd	20.26

Table 9 - Description of student engagement using VTK (Moodle).

E-Learning platforms	Domain knowledge and educational level			
	DK1 – No. Students	DK2 – No. Students	DK3 – No. Students	No. Students
CoLab Tutor	30 – grad.	5 – undergrad.	0 – undergrad.	
AC-ware Tutor	12 – undergrad.	12 – grad.	0 – undergrad.	
CM Tutor	14 – grad.	1 – undergrad.	3 – grad.	
Moodle	2 – undergrad.	5 – undergrad.	4 – grad.	
Total graduates	44	12	7	63
Total undergraduates	14	11	0	25
Total	58	23	7	88

Table 10 - Description of student engagement using VTL and VTK, and per educational level.

In total, there were 88 (13%) the most engaged and the most successful students in this research study out of 649, or more precisely, 44 (76%) graduates and 14 (24%) undergraduates for DK1, 12 (52%) graduates and 11(48%) undergraduates for DK2, and only 7 graduate students for DK3 (Table 10).

As for log data generated during online learning and domain knowledge acquisition, a total of 183.969 online learning records (OLR) were stored. Out of total online learning records, 135.422 of them were generated by undergraduates and 48.547 by graduates respectively. The most active group of students was the group (G4) using the AC-ware Tutor that generated 56.009 records and the group (G11) using the Moodle that generated 37.930 records. Presumably, the number of logs generated can be associated with the students' motivation and perseverance during the research study and/or the level of domain knowledge they were familiar with. In the post-study analysis and communication with students, we were able to explain students' behavior. Moreover, we realized that students' approach to learning was rather irresponsible and inconsistent. While using the e-Learning platforms, students deviated from the expected norm of behavior since they reported: (i) using mobile phones to take photos of online lessons or taking screenshots of them, avoiding concept learning that facilitates testing, (ii) opening of another browser (screen) to facilitate testing, (iii) they did not follow mastery-based learning, and they skipped the given lessons using available menu of assignments and learning tasks. For a number of students, the above-mentioned behavior was obviously a distraction and an obstacle to reaching the post-test success.

6. Conclusion

This research study presents a model developed to track student engagement and domain knowledge acquisition using two sets of variables, those tracking student's learning activities (VTL) and variables tracking student's knowledge (VTK). To the best of our knowledge, there are no recent works dealing with 13 variables classified into two sets, which are common for the four e-Learning platforms, regardless of their different functionalities. Learning analytics was deployed to track student engagement or non-engagement as well as their success in a blended learning environment with rotation model and flipped classroom sub-model. The presented data showed that a model designed to track student online learning and knowledge acquisition can be formalized for the four e-Learning platforms and described using VTL and VTK during the learning, teaching and testing processes. However, a significant decline in the number of students engaged in the online course is rather unexpected and discouraging. It can be associated with the lack of students' motivation, perseverance but also with distractions they reported in the post-study analysis. Namely, out of 649 students in total, only 88 students satisfied the highest criteria for engagement; they passed through all courseware elements and had the final test score above or equal to 50 points. Out of these 88 (13%) the most engaged students, 53 (22.27%) of them were graduates and 25 (6.08%) undergraduates. These qualitative and quantitative data indicate the need for e-Learning strategies in higher education that would improve student engagement and reduce the risk of dropping out. Our experience so far shows that future research should aim to enhance students' motivation and critical thinking, their more responsible approach to online learning and knowledge acquisition as well as their appropriate rewarding.

Availability of data and materials

The dataset used and analysed during the current study is available from the corresponding author on reasonable request.

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Digital technologies integration in teacher education: the active teacher training model

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Abstract

The objective of this research was to identify the theoretical and practical bases that contribute to a model that will allow the implementation of an innovative teaching-learning model for the integration of digital technologies in teacher education. This model of teacher training, based on identified pedagogical trends, was characterised by a flexible approach to the training process, including active training strategies that encourage the acquisition of diversified skills, including digital. This approach can also transfer to students skills which enable them to take responsibility for their learning and creation of their own knowledge. The research method used was two-fold: i) action research in the development of training workshops in an in-service research training project and ii) a case study in a pre-service teacher education study, in Portugal. It was found in this study that the participating teachers were able to develop skills and integrate digital technologies in their own teaching-learning process and could change their teaching practices, which will support the development of online education in the future.

KEYWORDS: Digital Technologies Integration; Active Teacher Training; Training Model; Teacher Education.

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1. Introduction

Digital technologies have revolutionized practically every aspect of our lives and work, "we live in an exponential time" (Mishra, Koehler & Henriksen, 2011, p. 23), and it is fundamental in this complex digital landscape to face the challenges posed, especially those responsible for education, in order to enable students to participate fully in the economic, social and cultural life (OECD, 2015).

With recent changes in the world, this issue takes on greater relevance, because it is necessary to continue to invest in the teacher education in training for distance learning as an appropriate innovation (COL, 2020).

There is still a long way to go for a more complete integration of Digital Technologies (DTs) in schools and teaching, according to Area, Hernández, & Sosa (2016). They have identified two patterns of pedagogical use of DTs in classes: a weak model, in which DTs are being used simply to transfer knowledge; and an intensive model in which DTs are used every day or several times a week in a variety of individual and group tasks, with research and development of digital resources, content creation and online communication, by teachers and students.

Accepting that "technology can amplify great teaching but great technology cannot replace poor teaching" (OECD, 2015, p.4), it is clear that the adaptation and integration of DTs in the classroom of contemporary society's schools requires the adoption of new roles and forms of work by the teacher. It also requires reflection and analysis of the effects of this new relationship, with the training of teachers as a key factor in the process. See, for example Goeman, Elen, & Pynoo (2015) or

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Johnson, Becker, Estrada, Freeman, Kampylis, Vuorikari, & Punie (2014).

The research described here aimed to contribute to this new kind of work with a proposal for the design of a training model and definition of a specific strategies, named Active Training (AT).

For this purpose, in addition to a literature review, two pieces of empirical work were conducted:

- an in-service research training project, in a given educational community;
- a case study in a pre-service teacher education class of the Masters in Economics and Accounting Education.

Both studies, conducted in Portugal, focused on the construction and development of teachers' skills, especially thinking reflectively, acting autonomously and integration of digital technologies, and active methods and teaching strategies that integrate digital technologies.

2. The integration of digital technologies in the teaching-learning process

2.1 The need for change in the new technological paradigm

The educational use of ICT has imposed fundamental challenges to education researchers and training institutions, which require changes "in both what has to be learned and how this learning is to happen" (Voogt, Erstad, Dede, & Mishra, 2013, p.403).

There is a need to promote transformative learning by emphasizing the roles that transdisciplinary thinking and the latest technologies can play in the creation of 21st century transformative teaching and learning (Mishra et al., 2011).

While not minimizing the importance of the proliferation of computer equipment, "spreading the Internet or putting more computers in schools, by themselves, do not necessarily constitute major social changes" (Castells, 2006, p.19). Integration will depend on how technologies are used. This author considers that one of the key aspects of the network society will be the total reconversion of the education system, with new ways of relating technology, pedagogy, content and organization of the learning process.

Thus, the scope of change clearly requires a new form of learning, amenable to the changing world, allowing the development of diverse skills with an emphasis on higher order cognitive processes, such as critical thinking and creative problem solving (Mishra et al., 2011). These authors also suggest that students engage in technology-rich learning contexts where they work collaboratively to solve complex and multidisciplinary problems.

Although some progress has been made in this direction, the integration of digital technologies is below what is desirable at the present time (Area et al., 2016; Glass & Vrasidas, 2005; Goeman et al., 2015; Mishra et al., 2011; Morris, 2012; OECD, 2015; Voogt et al., 2013).

Voogt et al. (2013) confirm "a lack of integration of 21st century competencies in curriculum and assessment, insufficient preparation of teachers and the absence of any systematic attention for strategies, innovative teaching and learning practices."

Goeman et al. (2015) add that training in the DTs field should promote teachers' thinking reflectively so that they acquire the skills to face the future evolutions of technology in education teaching models. For example, using innovative methods that incorporate collaborative work or project work, related to more active and directed pedagogical approaches to situations and real problems of society.

2.2 Difficulties and challenges of integrating digital technologies

Brown-L'Bahy (2005) argues that there is evidence that technology can improve students' learning and development, but considers that there are also difficulties in its integration. The main problems encountered in integrating DTs were time constraints, inadequate training and the need for rigorous assessment methods. These give compelling reasons for schools to commit to this issue.

In a study on the progress of ICT in education (BECTA, 2005), these problems were jointly identified as obstacles to ICT adoption. In addition to lack of time to learn new technologies, also mentioned were lack of access to computers and technical support, lack of confidence, resistance to change and lack of perceived benefits in their use. With regard to Continuing Professional Development in ICT (BECTA, 2010), external factors with the greatest impact are: the provision of external training actions to meet individual and institutional needs; the need for experienced human resources within institutions; a robust ICT infrastructure and support; and the provision of appropriate training actions in duration and time.

However, according to Morris (2012, p.3), "despite successive government training initiatives, policies and extensive funding over the last 15 years, little has been done to effectively tackle the disparity of ICT skills and the training of the UK teaching workforce".

Based on several studies, Rodrigues (2018) also identified some of the most common difficulties and constraints in the integration of DTs and consequently highlighted as challenges:

- lack of time for teachers to train and use DTs,
- the lack of technological resources for the use of digital technologies with students,
- the need for adequate support and training for the pedagogical integration of DTs in the teaching-learning process,

- the definition of clear objectives and the solid structure of the model of training and evaluation with DTs,
- the overcoming of intrinsic factors, namely those of resistance to change,
- the teacher's low vision of the pedagogical potential of DTs,
- the importance of the role of leadership in the teacher education process (p.369).

Therefore, given the factors that influence the pedagogical integration of DTs, teacher training and the necessary associated strategies and methods must be emphasized.

2.3 Teacher training for the integration of digital technologies

In this context, in order to ensure the integration of digital technologies in schools, teachers need to be trained and supported, so that they feel able to integrate them, both from a perspective of active citizenship and as a prospect of professional development, either in pre-service or in-service training.

In addition, it is intended that the training model used with teachers be used by those teachers with their students. This transfer of skills is called isomorphism (Mialaret, 1990).

Vrasidas and Glass (2005) also claim that efforts to integrate technology must be systematic, with teacher training programs taking place in a collaborative environment resulting from strong research and evaluation. Teacher training models should not be based on one-on-one sessions, but rather on communities that provide ongoing support and the resources that teachers need to integrate DTs.

When teachers with experience in teaching with technology form a community of practice, they provide support for the continuous exploration of technology and the reinforcement of the learning process. However, schools need to analyse their structure, where teachers often work in isolation and react defensively to innovation. It is necessary to develop strong professional communities that promote the habit of research and leadership building to help sustain the impacts of change, because in a community it is easier to integrate educational technology in an ongoing process of learning to teach (Riel, DeWindt, Chase, & Askegreen, 2005).

Thus, it is necessary to learn how to increase participation in communities of practice, focusing on learning in a continuous set of developing relationships (Lave & Wenger, 1991). According to these authors, this concept is broader than learning by doing, since situated learning involves people as full participants in the world and in the construction of meanings, where there is an identity in relation to the group and interaction taking the learning as a social act.

Koehler and Mishra (2009) have designed the TPACK model, in teacher training and professional development. They found it served as the basis of effective teaching with technology integration, resulting from the intersection of three different types of learning contexts:

- curriculum content – Content Knowledge (CK),
- pedagogical methods – Pedagogical Knowledge (PK) and
- technological skills – Technological Knowledge (TK).

They affirm that this model allows one to visualize the process of integration of technology as a whole and to identify what is important in terms of teachers' knowledge in the use of technology for teaching (Mishra & Koehler, 2006).

Active teacher training for the integration of digital technologies

It is clear that change is necessary, that schools need to reflect society and that there is a need to integrate digital technologies into educational practices. In this context an alternative and innovative model of teacher training, named Active Training (AT), was designed (Rodrigues, 2017). The model is based on five structuring principles shown in Table 1.

3.1 Principles of active training

Active Training is used as a cross-curricular method of training (Principle 1). It can be used by students and teachers as a basic skill whenever necessary and considered appropriate to the objectives and syllabus content of any discipline.

The importance of cross-curricular training is reinforced by, and directly related to, the forms of collaborative work adopted. These will have an added value because they allow the sharing of enriching experiences among teachers of different curricular areas and levels of education. At the same time, it strengthens curricular flexibility with a cross-curricular teaching-learning process which bridges theory and practice.

AT is supported by a socio-constructivist approach, derived from Jean Piaget's cognitive constructivism and his main precursor Lev Vygotsky, who valued the social aspect of learning, arguing that it occurs through social interaction with teachers and peers (Arends, 2012). Thus, through social interaction and in response to environmental stimuli, students are pushed towards the zone of proximal development, a zone that represents the level of development where learning of new knowledge occurs (Vygotsky, 2001).

It is proposed that AT should include a face-to-face component and an autonomous work component, to be developed in an authentic social context. This makes it possible for the trainees to learn by doing, in the social context of knowledge production itself, that is, at school, among co-workers.

Structuring Principles of AT	Concepts mobilized
Principle 1 Cross-curricular training with integration into teaching of digital technologies in an authentic social context that supports human development.	Transdisciplinary Socio-constructivism Authentic social context On-the-job training
Principle 2 Training tailored to the needs and interests of trainees, differentiated and focused on skills, with flexible planning and content management.	Needs Analysis Differentiated education Skills Flexible curriculum management
Principle 3 Training based on a democratic and affective pedagogical relationship, with the trainer as a guide, for the critical and isomorphic reproduction of skills for students.	Democratic pedagogical relationship Affectivity Adult Education Isomorphism
Principle 4 Dynamic theoretical-practical training, supported by collaborative and cooperative work in a learning community, using active teaching methods and strategies in synergy with digital technologies.	Collaborative and cooperative work Active methods Project work Group research or peer work Flipped classroom
Principle 5 Training for construction and development of skills of thinking reflectively, acting autonomously, network communication, participatory evaluation and self-regulation, to create a community of practice that allows the social construction of self-knowledge.	Thinking reflectively Acting autonomously Connectivism Evaluation and Self-regulation Community of practice

Table 1 - Structuring Principles of Active Teacher Training
Source: Rodrigues (2017, p. 62)

Training tailored to learners' needs requires differentiated teaching, whether due to the differences in the cognitive stages, knowledge and skills of the trainees, or their different learning styles and preferences. This can be brought about through planning and flexible content management and cooperative learning. A widely used practice is flexible group work, in which each group of students works on different content (Arends, 2012).

Principle 2 argues that training should be tailored to the needs and interests of trainees, with flexible content planning and management.

So, AT is based on flexible management of curriculum and content in which teachers and trainers assume curricular development as a dynamic and reflexive process, associated with collaborative and cooperative practices that seek to build and develop the skills of all students.

In Principle 3, building on cooperation and experimenting with students' values and skills, this democratic relationship also presupposes a cooperative management of content, as well as the use, sharing and communication of information and culture.

Thus, AT considers the trainer as a manager and guide of learning who seeks to create an environment of autonomous, participatory and democratic development. In this, an affective pedagogical relationship assumes particular relevance. Vygotsky (2001) also addresses this aspect, considering that emotional reactions have a substantial influence on our behaviour and the educational process, and that it is easier through the emotions to influence behaviour, seeking activities that are emotionally stimulating.

Mialaret (1990) advances the concept of isomorphism in which the type of education received by the teacher will later be used for educating their students. AT intends that this concept of isomorphism be used.

Principle 4 considers that training should be based on a dynamic theoretical-practical perspective. It uses collaborative and cooperative work and active teaching methods and strategies in synergy with digital technologies. According to Hargreaves (1998), collaboration can foster the professional development of teachers, providing situations of mutual learning and promoting individual reflections.

The intention is to use collaborative work among trainees in which they work to the same objective. Tasks and responsibilities in a group are decided by the members of the group working as a team.

In AT, the following strategies are the most important: project work; problem-based learning; group research or peer work, including Internet research; discussion, with reflection and communication; and flipped classroom.

A flipped classroom involves reversing the teaching-learning process, in which the teacher prepares teaching resources for the students in advance and makes them available in a Learning Management System (LMS). Later, the class discusses the materials presented. Thus, content is transmitted outside the classroom and lesson time is more usefully used by students to apply the content while the teacher guides them, answers questions, and makes suggestions (Baker, 2011).

Lastly, Principle 5 proposes training for the construction and development of the following skills: i) thinking reflectively about pedagogical work carried out; ii) acting autonomously in the search for new knowledge and new practices; iii) network communication with integration of DT; iv) participatory evaluation and v) self-regulation, in order to create a community of practice that allows the social construction of self-knowledge.

Knowledge, training and the formal and informal experiences of teachers contribute to their identity as a teacher. This is something that they are constantly building and renegotiating throughout their lives (Wenger, 1998). For Fullan and Hargreaves (1992), professional development of teachers takes place within a culture of teaching in a real context. Knowledge and skills develop as teachers interact with each other in a community.

Siemens (2003) says that what we know is less important than our ability to continue to learn more. Thus, we must ensure that the connections we make, especially in specialized communities allow us to maintain the flow of knowledge and to continue learning. In our field, technology is a facilitator of learning and a creator of connections. The more complex the learning needs and the faster the field of knowledge evolves, the greater is the value of a learning community.

The emphasis on increasing skills faces another challenge that is how to carry out their evaluation. In AT it is proposed that evaluation is essentially formative, carried out as a participatory, formative, interactive and differentiated process, in which teaching means helping, managing and orienting, so that the evaluation allows self-regulation by the learner. According to Fernandes (2006), formative evaluation is an essential pedagogical process to "improve what one learns and, more importantly, how one learns" (p. 43), contexts being constituted "by multiple cognitive, metacognitive and social processes which interact with each other such as feedback, teacher and student regulation, self-regulation and self-assessment " (p. 41).

The importance of creating a community of practice is emphasized, where one learns, builds and manages knowledge (Lave & Wenger, 1991).

3.2 Method of Active Training

Active Training is intended to be a model of teacher training in a broader perspective and at the same time a training method, in which it defines a specific way or way of “doing” to organize teaching and learning situations. It can be used not only for a particular content or thematic unit, in a training module during the term, but also for the whole training period or school year.

This method starts from the curriculum or program of the discipline, in which the subjects and contents of work are first presented to the trainees. Groups or work pairs are formed and the thematic areas to be addressed are distributed. These may be similar, complementary or different between working groups depending on the specific subject area or content. Preferably work should be in the form of a project, such as shown in Figure 1.

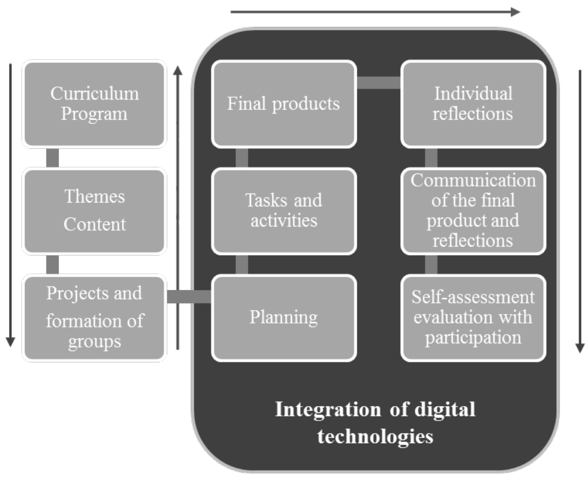

Figure 1 - Method of Active Teacher Training
Source: Rodrigues (2017, p.88)

However, project work can also take other forms, such as using the flipped classroom method and b-learning (online and face-to-face teaching), using a LMS.

After clarifying and negotiating the projects, each group will begin to plan the work, distributing and organizing individual tasks. During practice and while doing the projects, whether in face-to-face or non-face-to-face training sessions, support and guidance is provided by the trainers to each group. Autonomous, non-face-to-face work should be planned and monitored through online teaching using digital technology as a tool to support learning and communication.

The completed projects of each group, the individual reflections and online communication form the basis of the summative evaluation which complements the formative evaluation. The final evaluation should also assign a portion to self-assessment and participatory evaluation, as a way of joint reflection.

3.3 Model under construction

The model of Active Training (AT) arose from an investigation, started in 2014, and developed in workshops of in-service training of teachers that took place during the years 2015 and 2016. It also arose from work done in 2016-2018 in Didactics and Professional Practice of the Master’s Degree in Teaching Economics and Accounting.

After defining and experimenting with the AT model in different contexts, it was restructured to make it a more coherent training model. The main change was a more effective integration of assessment into the teaching-learning process.

Earl (2003) introduced the notion of Assessment as Learning to reinforce and extend the role of formative assessment for learning, emphasizing the learner’s role, not only as a contributor to the process of evaluation and learning, but as the link between them. It is a regulatory process of metacognition, when students monitor what they are learning and use feedback to make the necessary adaptations and changes.

Black and Wiliam (2003) had already verified that summative assessment should be aligned with formative assessment, since the latter increases attention and long-term retention of information by students. This requires active intervention by the students and also the need for teachers to promote the creation of knowledge through the provision of feedback.

Hattie and Timperley (2007), say that giving and receiving feedback requires skills for both teachers and students. These skills involve stimulus and response routines that require a good control of the classroom environment and the ability to deal with the complexity and diversity of judgments and contents in order to be able to establish relationships between ideas and promote self-regulation of learning. It is also necessary to consider the time required and the importance of managing this time.

Some tasks can lead to more effective feedback and better learning when students share learning objectives, adopt self-assessment and evaluation strategies, develop error-detection procedures, and increase self-efficacy in more challenging tasks. That is, feedback is only effective when students are committed to the learning objectives and when it is related to the learning achievements (Hattie & Timperley, op.cit).

Also, according to Nikou and Economides (2018), with the growth in the use of technologies associated with education, in particular of mobile technologies, there are other fields of study that can bring formal and informal learning opportunities, such as personalization and adaptability, context awareness, interactivity, communication and collaboration among students, the Mobile-Based Assessment (MBA).

Traditional assessment practices are not always appropriate to evaluate skills related to real-world tasks and higher-level skills such as problem solving, creativity and collaboration. However, Nikou and Economides (2018) proposed the development of the use of personal digital mobile devices such as smartphones or tablets to use in assessment. This study presents a review of forty-three articles published between 2009 and 2018 related to evaluation based on mobile devices. It was possible to conclude that the majority of articles analysed had a significant positive impact on students' performance and learning, as well as on the motivation for learning. It reported students' positive attitudes and perceptions about MBA.

Another study of evaluation feedback, Mobile Learning Framework for Assessment (MLFAF), showed the importance of the use of students' personal devices for feedback from evaluation, with the aim of fostering dialogue with students (Bikanga Ada, 2018).

However, for this process to be effective it is fundamental that support and training in technologies, teaching and learning be tailored to individual needs and context. This enables personalized assessment feedback to be given, for these practices to be integrated into the curriculum, and for choices and flexibility to be given to students.

4. Method

This research, based on a predominantly qualitative approach, proposes a training model and a specific strategy, Active Training (AT), that introduces new methods of teaching, assessment and learning integrating digital technology.

Starting from the initial question: What factors, methods and training strategies can influence an effective pedagogical integration of digital technologies? and going beyond the theoretical review of literature, empirical work was developed through i) a research-training project, in-service training; and (ii) a case study in a pre-service training class, both developed in Portugal.

4.1 Research Project in in-service training

In this project in-service training of teachers was used as an Action Research method, which focused on the practices of teachers from a perspective of personal and professional training and development. It aimed to promote the application of AT in the school where the research-training project was developed.

The project consisted of three training workshops each with a duration of 15 hours of face-to-face work and 15 hours of autonomous work. The participants were 35 teachers from a cluster of public schools. They covered various disciplines from pre-school to lower school (KS3). Evaluation questionnaires were given to the participants at the beginning and end of each workshop.

These workshops, following AT principles, included diverse content related to the integration of digital technology. They aimed to stimulate innovative practices designed and tested by the teachers themselves in the school.

4.2 Case study in pre-service training

This study sought to complement the previous one by experimenting with teaching and learning methods, linked to evaluation and integrating digital technology. It was anticipated that this would be effective in incorporating the Active Teacher Training model into pre-service teacher education.

The case study method was applied, in specific Didactics and Professional Practice disciplines, in a class of seven students from a Masters in Teaching. The AT model was used, paying particular attention to the development of formative assessment integrated into the teaching and learning process.

The teaching-assessment-learning strategies developed were: the analysis, presentation and discussion of texts and articles; the construction of learning scenarios; the elaboration of didactic materials and resources; the simulation of teaching-learning situations with participatory evaluation; observation and teaching of classes in a cooperating school; critical reflection on professional practice; and the performance of group work; using digital technologies for communication. All activities used formative evaluation with feedback.

The case study is a widely adopted method in research in education. It is used particularly when the researcher is confronted with complex situations in which it is difficult to select variables, but in which one tries to describe and analyse phenomena and their interactions (Yin, 1994).

Data collection consisted of a field diary through participant observation, learning scenarios carried out by the students, and photographic and video records. The participant observation, using a systematic record, consistently sought to present a high level of accuracy of the information and its analysis (Bogdan & Biklen, 2007).

5. Results

As well as the quantitative treatment and analysis of the data from the questionnaires, a qualitative approach was also used (Johnson & Christensen, 2004). The analysis of the texts of interviews, field diaries and teachers' reflections were particularly important.

The analysis of content of these instruments was performed through categories and frequencies, according to Bardin (2011), in order to organize information and analyse regularities (Miles & Huberman, 1994).

5.1 Action Research Project

In this research, four questionnaires on the use of digital technology were given to the participants.

The questionnaire applied at the beginning of the project revealed that teachers used digital technology to support the transmission of knowledge and to prepare classes. They had taught themselves to use computers with the help of more experienced colleagues. Their aim was to deepen their knowledge and build teaching materials to support students' autonomous work.

Exploratory studies identified the most common challenges identified in the literature regarding the pedagogical integration of DT in the teaching-learning process, namely: the lack of time or time management of teachers for training and DT use, the need for support and adequate training to pedagogical integration of DT, effective resource management and insufficient technological resources for use by students, and are also highlighted, intrinsic factors, such as resistance to change and the need for information in terms of privacy and security.

The field diaries and reflections of the trainees confirmed that the training workshops generally took place according to plan. Active Training had been applied with very good results, particularly in terms of flexibility in the management of the program and with collaborative work. The trainees were always committed and motivated, having developed projects and activities with their students that integrated digital technologies.

In the Methods and strategies category the use of software with Internet support was emphasized. This enabled the trainees to use diverse work strategies, such as creating online workgroups, viewing videos, creating events and scheduling presentations, promoting a discussion forum and exploring various pieces of software. On-line assessment tools and web quests were developed. Tutorials and micro-classes were provided using video, also synchronous online sessions in chat and a video conference with a guest. There was the possibility of using clarifying questions with students in an extra on-line class.

Concerning the Activities developed by teachers, the ones with the highest frequency were: quiz building, concept maps and flash cards, creating groups and pages on Facebook and websites, preparation of worksheets in Google Forms, creation of e-books with students, and writing and creating characters in Voki. The use of email was mentioned by several teachers. Also mentioned was the use of a closed group on Facebook maintained throughout the entire training project, and aiming to have continuity after its completion.

About Characteristics of the model and training method used, the training was enriched by including teachers from several curricular areas. The importance of differentiation instruction and the flexibility and freedom given to the trainees to choose the activities and projects were confirmed. The support of trainers as consultants was a facilitating factor in the use of digital technology.

The last follow-up questionnaire confirmed the success of the training project and the satisfaction of the respondents with the training workshops. They considered that these had improved their skills in the use of digital technology in teaching, providing them with professional development and allowing to renew and innovate teaching practices, with the creation of a community of practice.

5.2 Case study

In this case study, the teaching-assessment-learning strategies developed in the initial seminars were:

1. group presentations of scientific articles by the masters students with discussion in a large group,
2. the construction of learning scenarios of a curricular unit with materials and educational resources necessary for its development, and
3. evaluation tools.

In the subsequent seminars, the master's students did simulations of parts of classes, with reflection and critical self-analysis on them. A chat session was also developed through Facebook with analysis and debate of a text. In the various activities referred to, the students were given continuous feedback, either oral, in the discussions, presentations and simulations of classes, or in written form.

In the subjects of Professional Practice, the master's students did coordinated work in the institution of higher education and in the cooperating schools. The field work in these schools involved the teaching of classes or parts of classes by a cooperating tutor. This included the preparation of a field diary describing and reflecting on the activities carried out.

The digital technologies associated to active methods were used in the strategies and the activities developed in the Masters in Teaching. They were integrated in an intensive way, be it in the distribution and organization of the work by the teacher, or in the work developed by the master's students. Different equipment was used, such as laptop, smartphone, and the FTELab room, and also various software and applications, namely Moodle, Facebook, Google Classroom, Prezi, Excel, Kahoot and Padlet.

6. Discussion

In this study, with regard to in-service training research, it was found to be important teachers could see that the use of digital technology is effective, that it increases their freedom of action and allows them to check the progress made by students both inside and outside the classroom. Its use by teachers is also influenced by the motivation shown by their students. This may be a determining factor in the continued integration of digital technology.

It was observed that through experimentation, teachers effectively realized the potential of integrating technologies in the teaching-learning process. Thus, there was an increase in their autonomy in the development of activities with students, which allowed them to verify the advantages and gains with the use of DT in educational practices, including in terms of improving learning.

In addition, the AT model allows pedagogical differentiation, through the proposed active methods, which allows teachers with different levels of proficiency in digital technologies to be covered and that they have acquired experience and autonomy for the integration of DT.

The most significant and constant constraint was the shortage of teachers' time and overwork in general.

In the study of the pre-service teacher education, the trainees did all the work requested.

It was confirmed that:

1. it was possible to differentiate groups according to the needs and interests of the trainees and to carry out the work in an authentic social context;
2. it was appropriate to plan learning scenarios using active methods, based on collaborative work, which allowed the social construction of students' own knowledge;
3. diversified skills, namely digital, reflexive and self-regulation could be developed in teacher education;
4. continuous evaluation supported by feedback could be developed;
5. the isomorphic reproduction of skills for their students, particularly technology skills, was observed in the classes taught by the master's students in the cooperating schools.

In both studies, the issue of building and developing skills proved to be crucial, made possible by the use of active teaching, assessment and learning methods, such as debates, experimentation, project work and cooperative work. An effective increase in technology skills was observed in all participants, with many teachers and future teachers mentioning their intention to continue to use and integrate TD in their classes.

In this way, the development of skills, stood out as an added value of this training method, both digital and also in terms of reflexivity and autonomy. Provided the teachers with the opportunity to create their own knowledge and to reflect on their teaching practices and, simultaneously, to promote the same process among their students, which contributed to the personal and professional development of teachers and to a more digital culture in schools.

7. Conclusion

In this research the main aspects in the design, construction and implementation of the Active Teacher training model for the integration of digital technology into teaching were analysed. This verified the possibility of developing innovative teaching methods and strategies used by teachers.

It was concluded that, in the design of a teacher education program with integration of DT in the teaching-learning process, it will be essential to provide the effective use and experimentation of DT by the trainees, which will facilitate the development of their technology skills.

In turn, this integration of technology requires a relatively complex understanding of the interconnection of technology, pedagogy and content concepts (Koehler & Mishra, 2009), with the use of active teaching, assessment and learning methods. Considering that technology is not only a tool to motivate and assist teachers to implement new methodologies, it has also become a source of knowledge for teachers in providing, sharing and exploring content with students.

For future applications it is essential to note some issues for research particularly in in-service education. There is the need to find time and resources for teachers to develop their skills and to integrate digital technology into their teaching. There is the need to reduce bureaucracy and administrative work. Above all there is the need to reduce workload or to clarify the definition of hours allocated to training.

The question of the importance of collaborative work is also very relevant, and its development in the teacher education is fundamental, namely for the construction of a community of practice. These, particularly in the use and incorporation of DT in an educational context, have significant added value, especially in a perspective of continuity and professional development, as they allow the sharing of information and knowledge, resources and materials, experiences and pedagogical practices, in a joint reflection and knowledge construction.

A community of practice can be promoted in different ways, for example, by encouraging teachers with greater proficiency in the integration of DT to become consultants of colleagues, in a perspective of coaching and mentoring, in supporting and experimenting activities or projects with technologies and new methodologies and strategies. This type of processes can generate improvement efforts, provide collaboration and cohesion strategies, allowing the change and the development of new knowledge and skills of teachers.

These forms of collaborative work assume considerable relevance in contemporary society, in the sharing of knowledge, in the development of social, interpersonal and higher-level thinking skills, promoting increased motivation and knowledge retention of trainees and students in more meaningful learning.

Other issues that should be addressed at the level of public policies would be certification of training, promotion of free training courses, and consideration of the weight training receives in the performance evaluation of teachers and its contribution to career advancement.

In this way, it is considered that the development of training must be socially binding, projecting a community of democratic and efficient practice that promotes the creation of a digital culture in the school for the integral formation of individuals, where they can get involved in practices cooperative work, with balanced interception of content, pedagogy and technology.

In short, the Active Teacher training model, with its structuring principles and specific methods, confirmed the possibility of developing strategies to integrate digital technology into the teaching-assessment-learning process, which will support the development of online education in the future. It also developed skills associated with pedagogical and didactic knowledge, both in pre-service and in-service teacher training.

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Simplex didactics: promoting transversal learning through the training of perspective taking

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Abstract

Several studies have focused on Visual Perspective Taking (from here on out "PT"). PT refer to the capacity to elaborate space from different perspectives. Research results led to the hypothesis that such an ability constitutes a milestone in the development of an individual's social skills, more specifically empathy, whose full development is at the basis of numerous school-related competencies. Even the national educational system seems to recognise the central role of the development of such skill in students' learning. To date, there is a lack of studies and teaching methods specifically designed to favour an adequate development of PT. The objective of this paper is to present the results of the validation of an edugame specifically designed to measure and promote the PT skill development.

KEYWORDS: Didactics, Edugame, Simplexity, Perspective Taking

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1. Introduction

In the late 1900s studies concentrated on better defining how the manipulation of space constitutes a prerequisite for the development of empathy in individuals. In particular, neuroscientific research identified the ability of spatial, (also referred to as visual and perceptual) PT a fundamental prerequisite for the development of empathy and agency (Underwood, 1982; Oswald, 1996; Ruby & Decety, 2001, 2003, 2004; David, 2006; Berthoz, 2006, 2011; Sibilio, 2017; Girelli, 2018). This ability has been considered a key milestone for the development of individual's social skills because "the capacity to know where another individual is directing attention in space and what he or she is seeing on the current visual scene, which we refer to as 'visual perspective taking', provides critical information for monitoring social interactions. It is likely a prerequisite to understand another's intentions, actions and emotional reactions, as well as to adapt one's own behaviour to the current situation" (Lambrey, 2008, p.523). Therefore, PT ability is at the basis of shared attention and constitutes one of the fundamental prerequisites for inter-individual differentiation. Psychological research has shown that these abilities depend on two cognitive systems to elaborate space (egocentric and allocentric) (Cornoldi, 2004; Surtees, 2012). Cornoldi links these two cognitive systems to the individual's motor skills and therefore to the individual's body in movement and describes them in the following manner: "As underlined above, the evolution of spatial competence has been linked to motor functions; thus the ability to move and find one's way in the environment clearly requires an understanding of the spatial properties of that environment. It is possible to encode spatial information in an egocentric or allocentric representation (Foreman & Gillet, 1997). An egocentric spatial representation refers to spatial encoding of information as a function of body position or a self-centred system of spatial coordinates. On the other hand, an allocentric spatial representation is based on the relationship between two or more objects in space.

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This relationship is defined not by means of the body's orientation or distance, but in terms of their spatial relations. It is clear that both egocentric and allocentric spatial representations are linked to motor functions, either in terms of grasping and reaching abilities (egocentric representations) or in terms of body movement and navigational ability (egocentric or allocentric representations)" (Cornoldi, 2004, p. 14). Berthoz locates these two mechanisms at the basis of four elaboration and recall strategies of space. These are:

1. *egocentric strategy* – this is used when we visit a city, on foot or by car. It consists in remembering our movements, the detours that we are made to take, and associate them to visual landmarks that we perceive or experiences we have lived. We have defined this as "topo-kinesthetic" memory. It doesn't limit itself to a simple association between movements and sensory data… It permits the perceiving subject, in other words us, to attribute a continuity, a structural organisation and a synthetic unity to the manifestation of instant sensorial fields. The surrounding world is hence constructed by the brain on successive views or sequentially-organised points of view: of encounters, events that happened while walking. This process is fundamentally egocentric. This means that the point of view through which the world is analysed is in the "first person".
2. *allocentric strategy* - This allows to recall a mental map of the environment on which we can follow an itinerary as if it were a real map. Imagine the neighbourhood in which you live and the way from your house to the bakery round the corner: you can recall the way – the first strategy – or the mental map of the neighbourhood, that is the second strategy, said to be allocentric because it does not envisage the body. In fact, the environmental elements are linked without making reference to the subject's body that examines the space.
3. *heterocentric strategy* – If somebody asked us "how do I get to the post office from the hotel?", and we have to describe the way from this person's perspective, we have to take this person as a point of reference. This decentralization also happens when during a row, we try to understand the litigants' point of view.
4. *3D model strategy* – This entails constructing a mental model of a tri-dimensional structure (Berthoz, 2015, p.87).

Regarding this issue, Berthoz writes: at this point I would like to insist on the use of space to simplify some processes which are highly cognitive. In fact, it seems to me that the neural basis of mental manipulation of spatial frame systems (egocentric, allocentric, geocentric, heterocentric, proximal and distal space) constitute one of the foundations of our rational thought and, in particular, of the human being's attitude towards geometry, reasoning, change in point of view and logic. It seems that these neural basis in cooperation with the social brain, make intersubjectivity and empathy possible (Berthoz, 2011, p.107). The ability to take somebody else's perspective would derive from a complex activity of manipulation of space. Understanding what another person is looking at, in fact, implies abandoning our spatial perspective (egocentric coding), being able to manipulate space independently from our position (allocentric coding) and, successively use the other person's perspective as the points of origin of the axis (heterocentric coding). Always in relation to PT, some studies have also demonstrated how this ability is significantly influenced in diverse sociopathies that affect the development of social interaction (autism, schizophrenia, paranoia) (Langdon, 2001, 2006; Reed, 1990; Dawson, 1987) thus supporting the hypothesis that this competence is of fundamental importance for the development of complex social competencies. More recent studies have focused on the identification of the active cerebral areas during PT tasks carried out by the individual or a third person (Ruby & Decety, 2001, 2003, 2004; Vogeley, 2001, 2004).

1.1 PT: Its development in childhood

Throughout the 20th Century, attempts were made to identify the way how PT ability develops during childhood and how this is manifested in adulthood. In Piaget's initial studies "children under approximately 7 years of age tended to choose their own view as also representing that of another observer (Piaget & Inhelder, 1956). These findings have been widely replicated (Fishbein, Lewis, & Keiffer, 1972; Flavell, Everett, Croft, & Flavell, 1981; Flavell, Flavell, Green, & Wilcox, 1981; Liben, 1978). Generally, it has been observed that correct performance on a perspective-taking task declines as the number of stimuli in the array increases (Fishbein et al., 1972; Liben, 1978). Poorer performance is also associated with an increase of interposition of the elements within the visual array and a decrease in the overall visibility of the stimulus set (Coie, Costanzo, & Farnill, 1973; Flavell, Omanson, & Latham, 1978; Liben, 1978). The angle of orientation also has an effect on performance. Broadside views of an arrray are mastered be- fore the comer or diagonal views (Schachter & Gollin, 1979; Walker & Gollin, 1977)" (Gzesh, 1985). However, a number of studies seem to suggest that even if three-year-olds perform poorly in visual perspective-taking tasks it is already possible to note a significant difference in terms of PT task performance in four-year-olds (age in which, according to Piaget, children are in high egocentric stage), who, on average, already seem to be able to carry our sophisticated manipulations of 3D space.

Flavell (1981) and Masangkay (1974) propose splitting PT ability in two levels: “Level 1 refers to the ability to distinguish between what people can and cannot see, e.g., that people who look at different sides of a piece of paper see different things: a picture of a cat on the one and a picture of a dog on the other side. Level 2 refers to the understanding that, when people look at the same drawing or scene from different angles, they arrive at different and contradictory descriptions” (Aichhorn, 2006, p. 1062) (Figures 1 and 2). Studies suggest that already when they are 4 years old, children are able to complete Level 1 PT tasks and therefore it can be acknowledged that “this knowledge undergoes considerable development during preschool period, with many 4.5-years-old seemingly possessing it in the form of a general rule”. Studies conducted by Flavell in the 60s and 70s also seem to suggest that children between 5 and 5.5 years seem to have already acquired excellent Level I and II PT abilities (Beilin, 2013). Hence, Flavell affirms that “there is widespread agreement today that young children are not as totally egocentric as Piaget believed them to be, but also that perspective-taking abilities and related psychological knowledge do show marked increases with age, much as he said they did” (Flavell, 2000, p.18). Nevertheless, the hypothesis that PT ability is “mastered in early adolescence (Chandler & Greenspan, 1972; Flavell, Botkin, & Fry, 1968; Laurendeau & Pinard, 1970; Piaget & Inhelder, 1956) has been challenged by several writers on methodological grounds. Borke (1975), Fishbein, Lewis, and Keiffer (1972), and Shantz and Watson (1971), for example, have argued that the late acquisition of coordinating perceptual perspectives is a function of the complexity of the stimulus array and response mode” (Kurdek, 1975, p.645). A study conducted by Kurdek in 1975 seems to suggest that PT ability starts to develop in pre-school years (at around 4 years of age) and proceeds until adolescence (around the age of 11). As a result, “the present finding of an increase in perceptual perspective taking in the fourth through sixth grades confirms Nigl and Fishbein's (1974) contention that the ability to coordinate perceptual perspectives undergoes marked performance changes between the ages of 9 and 11 years” (Kurdek, 1975. P. 647).

1.2 PT, mental rotation and gender differences

The study of the relationship between space elaboration and empathy reaches higher levels of complexity due to the coexistence of diverse systems and strategies to elaborate space. In fact, the existence of inter-individual differences and, more specifically, gender differences (Berthoz, 2011) add complexity to the studies on space elaboration and, more specifically on PT (Grön et al. 2000; Lambrey, 2007; Cahill 2006). For example, “it is well known that, in a given gender, some subjects are more dependent on visual inputs and information in their relation to space, whereas other subjects rely on proprioception. We also know that there are important gender differences: Women tend to adopt more egocentric strategies than men, whereas men adopt more allocentric strategies than women. It has been long known that women are more “field

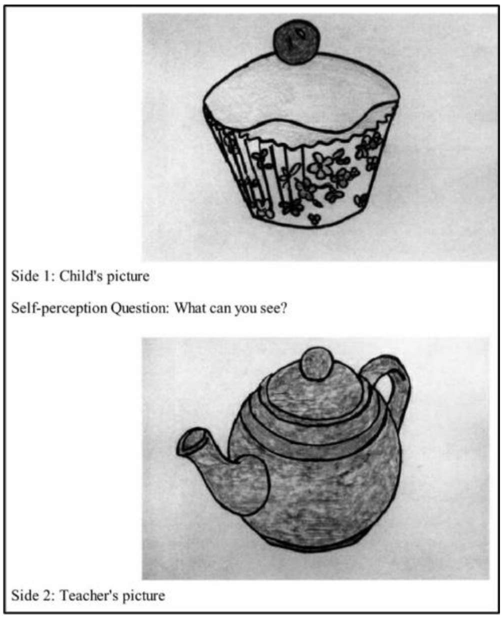

Figure 1 - Level I – PT Task.

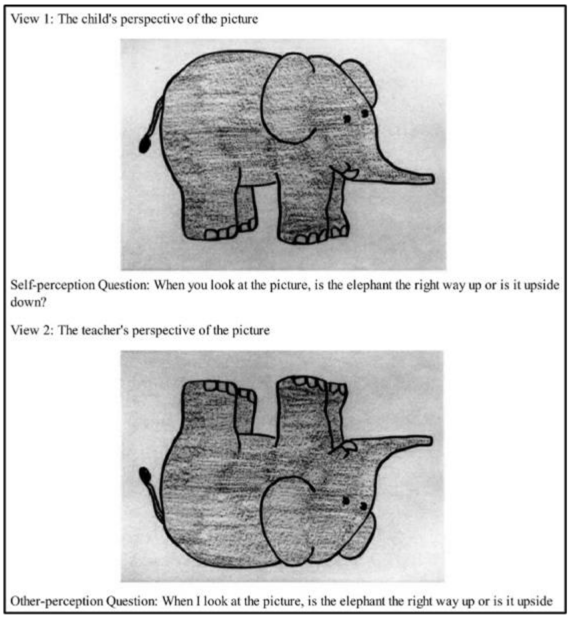

Figure 2 - Level II – PT Task.

dependent". This means that, for spatial orientation, women are more dependent upon visual references than men" (Berthoz, 2011). Moving beyond gender differences, literature seems to support the hypothesis that similar space elaboration tasks (such as imagining an object from different points of view and imagining that the object is rotating on its axis) require different cognitive abilities (PT in the first case, whereas Mental Rotation [MR] in the second case). The results conducted on this topic "suggest that the dissociation between tests of perspective taking and mental rotation reflects a distinction between ability to make egocentric spatial transformations (i.e., to imagine the results of changing one's egocentric frame of reference with respect to the environment) and ability to make object-based transformations (i.e., to imagine the results of changing the positions of objects in the environment, while maintaining one's current orientation in the environment)" (Hegarty, 2004, p 183).

Nevertheless, the distinction between MR and PT seems to be only partial. In fact, studies suggest that the MR and PT tasks shared a common skill (De Beni, 2006). Therefore, the two abilities not only seem to share some space elaboration skills but also the time when these skills develop. Indeed, various studies "showed that the elderly were less able than younger people in way-finding, route-learning and pointing tasks. Coyne and Herman (1980) found that the elderly was less accurate than younger people in a spatial perspective-taking test. Other studies (Lachman & Leff, 1989; Willis, 1991) support the adequacy of older participants in performing more everyday tasks. In Evans et al. (1984), ageing did not affect memory for salient landmarks or their position. Moreover, Kirasic (1989) found that the elderly was disadvantaged compared with younger people when having to solve spatial perspective-taking and mental rotation tasks operating on novel spatial configurations, but no differences between groups appeared when older people had to perform the tasks in a familiar environment. According to Kirasic (1985), elderly adults encountered problems only in learning new routes in unfamiliar areas. Overall, the pattern of results on spatial abilities in older people proved to be more disparate, indicating a dramatic drop in more abstract and laboratory tests but adequate performances in more everyday tasks" (De Beni, 2006, p. 815). In spite of the fact that the scientific debate seems to be heterogeneous, it is still possible to affirm that on the basis of what has been outlined in the section of PT development in childhood, PT ability matures in this developmental phase and presumably gradually deteriorates with time.

1.2 PT, Training Perspective Taking

A plethora of studies seem to demonstrate that the ability to elaborate space from an allocentric perspective could be trained through experience. Some studies have shown that the hippocampus of expert taxi drivers is bigger when compared to the average male drivers (Maguire, 1997, 2000, 2006). On the basis of the subjects studied, results have shown that these adaptations of the hippocampus is linked to a higher ability in tasks that require the allocentric elaboration of space. Therefore, the results correlate the spatial elaboration and navigation (derived from the taxi driver profession) to an increment in the ability of allocentric spatial elaboration. Therefore, an implicit result suggested by such studies is the ability to elaborate space allocentrically (and as a consequence PT ability) can be trained through specific tasks such as driving in big cities and changing the destination constantly (Chase, 1983; Maguire, 2000, 2003; Dünser, 2006). More specifically, studies have demonstrated the possibility to train PT by principally concentrating on subjects at a young age (Knoll, 2000; Rosen, 1974; Burns, 1979). In fact, Rosen (1974) reports a slight improvement in cognitive and perceptual perspective taking in kindergarten children who were given 40 hours of dramatic play training, while Cox (1978) reports significant improvements in PT ability in school-aged children, which he measured through the use of quasi-mountain problems prior to and after 20 hours of training.

2. Methods: Research Hypothesis

On the basis of what has been delineated in the introductory part of this paper, one can affirm that:

1. PT is a prerequisite for the development of social skills and the acquisition of literacy and numeracy skills (Trisciuzzi, 2014);
2. PT ability develops between the ages of 4 and 14 and gradually deteriorates over time after the ages 65-70 (De Beni, 2006);
3. The cerebral areas that are activated during PT and Mental Rotation tasks partially overlap and therefore they are only partially independent (Hegarty, 2004, p 183);
4. PT ability is affected by various sociopathies linked to deficits in social interaction (Kessler, 2012);
5. PT ability can be trained and improved (Chase, 1983).

The points listed above provide an explanation as to why this theme is undoubtedly of interest to the field of education. The objective of this study is related to the development of an edugame aimed to be used as a research tool to:

- measure the level of development of PT ability in children aged between 6 and 11 prior to and following a systematic didactic method planned to foster PT skill development;

- promote the development of PT ability in children aged between 6 and 11.

The design and development of the edugame responds to the need of having a reliable and objective tool apt to measure the levels of PT ability prior to, during and after the didactic interventions, fundamental requirement to guarantee an acceptable level of objectivity in the subsequent research phases.

In designing the testing phase of this edugame a number of difficulties were encountered. This was mainly due to the fact that the availability of validated standardised tests apt to measure PT ability are predominantly designed for adults. Those for school-aged children are not as accurate and reliable and are less feasible to use in school contexts than the edugame developed. Hence, the testing phase included two steps:

1. the edugame was tested with adults to explore the possible relation between the scores obtained in the edugame and those measured using the well-known and validated PTSOT test.
2. On acknowledging the fact that children are not 'little adults' (Remuzzi, 2015) and subject to the correlation emerging from the first step in the testing phase, a paper-and-pencil test was compiled. The items included in this test were extrapolated from other tests available in literature and those administered in national examinations by the Italian National Institute for the Evaluation of the Educational System. The aim was to demonstrate if and to what extent the edugame was able to measure the level of PT skill development among children – taking into consideration the differences between level I and II PT ability and the existence of other more complex components of PT ability.

2.1 Methodology

The *first* phase of the research consisted of three steps:

- literature review on PT;
- design of the Edugame - Schoolcam;
- creation of the Edugame - Schoolcam.

In the *second* phase the edugame was tested to evaluate whether and to what extent the tasks proposed in the edugame actually required PT ability. This was done by administering two validated tests, one measuring PT and one MR ability, and the edugame. The results obtained from the three tools were then compared. This phase, which was conducted with a sample of adult participants, included the following steps:

- standardized tests to measure PT and MR abilities were identified;
- the research sample was identified;
- the edugame and the two tests were administered;
- data was analysed.

The *third* phase is aimed at testing the tool on children to evaluate at what age, on average, children are able to carry out the proposed activities. Another objective of this research phase was to test whether the activities presented in the edugame were actually able to provide an adequate measurement of the level of PT ability in the targeted age group. To this aim, the paper-and-pencil test compiled, mentioned earlier and explained in detail later in this paper, was also administered when the edugame was tested.

2.2 The development of an edugame to promote the development of PT ability

The edugame created consists of three different tasks. The first two tasks measure the PT ability at two different difficulty levels. The third task measures Mental Rotation ability (understood as an ability which is partially independent from PT). The three tasks are described in further detail below:

TASK 1: In this activity the user is presented with a 3D classroom (Figure 3). The screen is divided into two frames. The frame above shows the 3D classroom through a semi-allocentric perspective (bird's eye view at an angle of 45°). The frame below shows the perspective of one of the students present in the frame above. The user is asked to identify to which student the view shown in the frame below belongs. Every time the user gives the correct answer, one point is awarded. No points are scored if the answer is wrong or no answer is submitted within 15 seconds.

TASK 2: In this activity a 3D classroom is presented (Figure 4). The screen is divided into two frames. The frame on the left shows the 3D classroom through an allocentric perspective (bird's eye view at a 90° angle). The frame on the right shows the point of view of the student presented in the frame on the left. The user is asked to identify to which student the view shown in the frame on the right belongs. Every time the user gives the correct answer, one point is awarded. No points are scored if the answer is wrong or no answer is submitted within 15 seconds.

TASK 3: In this activity a compex 3D object is shown (Figure 5). The screen is then divided into two frames. The frame above shows the 3D object from a specific perspective. Instead, in the frame below 4 objects are shown from different angles. Out of these 4, two show the same object shown in the frame above from a different perspective. The user must identify the two corresponding objects.

Furthermore, the edugame proposes two gameplay modes. One is aimed at measuring the user's ability, while the second mode is used for training purposes. In the first mode, the sequence of the questions and the respective spatial configurations are always the same

Figure 3 - Schoolca edugame screenshoot: Student perspective (first task).

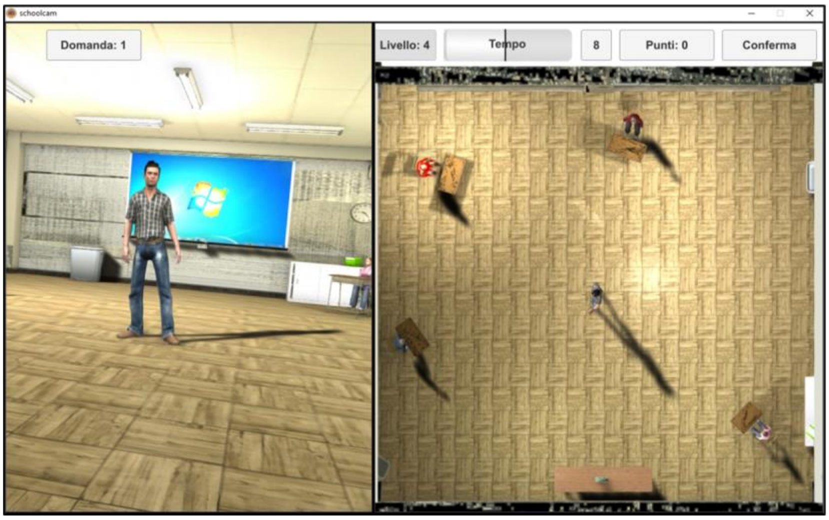

Figure 4 - Schoolca edugame screenshoot: Allocentric perspective (second task).

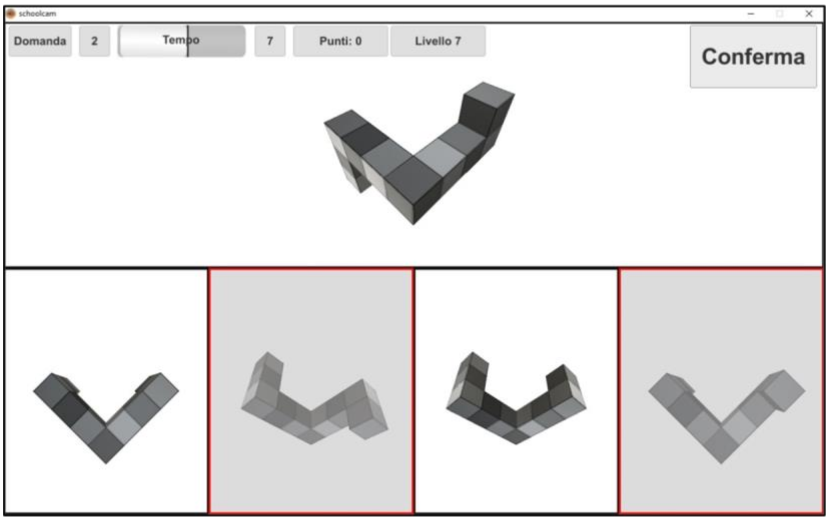

Figure 5 - Schoolca edugame screenshoot: Mental rotation task (third task).

and includes 15 questions, whereas the training mode the spatial configuration and the students and objects' positions are changed randomly. In both cases, the difficulty level gradually increases. The number of students increases with every 3 correct answers given, reaching a maximum of 15 students. The time available to answer each single question is 15 seconds. The edugame also has an automised system for data collection. The following data is recorded and exported in XLS and CSV formats:

- the time taken to give each single answer;
- the score for each question;
- the sequence of answers given for each task;
- the total score;
- the total duration to complete each level.

A demo video of the tasks and some experimental sessions can be viewed at: https://youtu.be/nkzjrVZKuek

2.3 Methodology – Phase II

The aim of the second research phase was that of validating the tool through the comparison of the scores obtained through the edugame and those obtained from the tests available in literature for the measurement of PT and MR competencies. The study involved a total of 122 subjects between the age of 30 and 63 (average age 48.6; SD 6.6). The methodology included the following steps:

- administration of the edugame;
- administration of the PTSOT and MRT-A tests (these will be described in the next section);
- data analysis.

2.4 Tests Used

As previously outlined, the first step in the testing phase consisted of administering two tests and the edugame. The first of these two tests is the PTSOT (Hegarty, 2004; Kozhevnikov, 2001) that measures perspective taking and spatial orientation abilities. Each of the pages includes:

- a group of objects
- a circle with an arrow
- a question related to the direction of objects from different perspectives (see Figure 6).

The instructions are the following:

"to answer each of the questions you should imagine that you are standing at one object in the array (which will be named in the centre of the circle) and facing another object, named at the top of the circle. Your task is to draw an arrow from the centre object showing the direction to a third object from this facing orientation" (Figure 6).

The score obtained in the test is simply calculated by measuring the angle discrepancy between that indicated by the respondent and the correct angle. Then, the average of the absolute values is calculated. Therefore, the test score is determined by the absolute average error, in terms of angles. Hence, the higher the score, the less the respondent's PT ability.

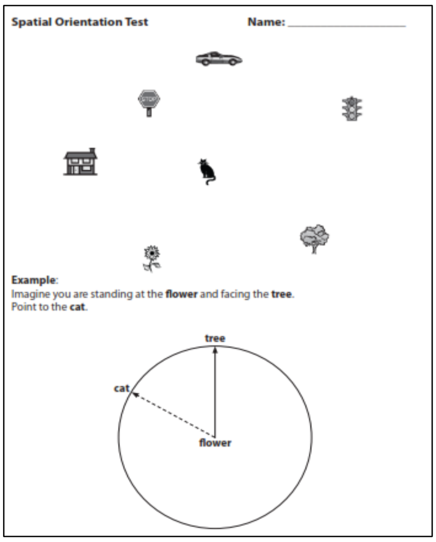

Figure 6 - PTSOT test.

The MRT-A (Peters, 1995) is a test which measures the mental rotation ability. Figure 7 shows the first page of the test with the instructions. Every time that the respondent chooses the two correct images that show the same image as the one on the left, a point is given. In this case, the higher the score, the higher is the respondent's mental rotation ability.

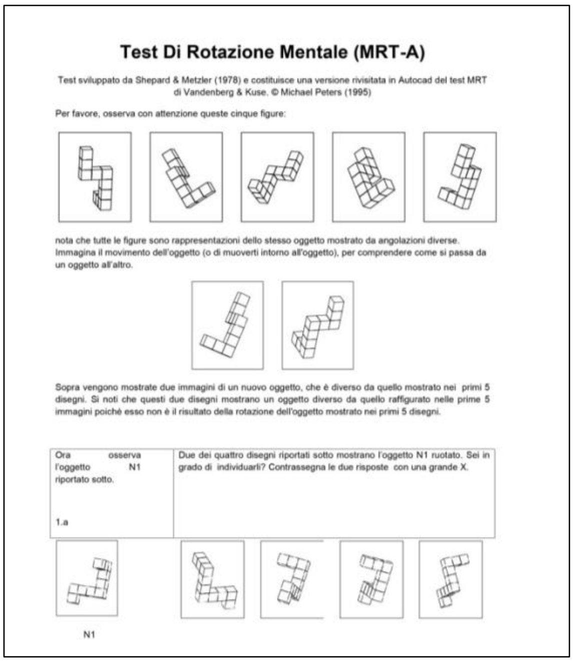

Figure 7 - Mrt-a TEST.

3. Results: Data analysis for phase 1

The PTSOT test, MRT-A test and the edugame developed were administered to 122 adults, aged between 30 and 63 (average age 48.6; SD 6.6). Table 1 presents the scores obtained, the time taken when playing the game (totals and subdivided per task) and the scores obtained in the PTSOT and MART-A tests. Table 1 presents the average scores obtained and the standard deviation values in the edugame by the 122 subjects.

Table 2 reports the standard scores available in literature and the average scores obtained in the PTSOT and MRT- A tests by the 122 participants.

As can be observed in Table 2, the scores obtained by the users in the MRT-A and PTSOT tests are below the standards reported in literature. Hence the Cronbach's alpha coefficient was calculated for the answers provided to measure the internal reliability of the test. The alpha coefficients are reported in Table 3.

The coefficients obtained are high enough to guarantee the internal reliability of the test. As a result, possible correlations between the scores obtained in the tests and those obtained in the edugame were calculated. Table 4 reports Pearson's R and R2.

In interpreting the data above, it is important to bear in mind that the PTSOT test measures the errors and so the higher the score the lower the PT ability, whereas the edugame scores measure the correct answers and so the higher the score the higher the PT ability. Therefore, as can be noted in Table 4, the obtained scores in the first task show a strong inverse correlation with the PTSOT test. Instead, the scores obtained in the second and the third task present a moderate correlation with the PTSOT scores. Even the total score shows a moderate correlation with the same PTSOT scores. There is a moderate inverse correlation between the scores obtained in the MRT-A test and the PTSOT test and a moderate direct correlation between the MRT-A test scores and the scores obtained in task 3 of the edugame, which was specifically designed to measure mental rotation ability.

A T-Test was carried out using the PTSOT and the MRT-A test scores. The T-test indicated a significant difference in terms of performance between the two tests ($p<0,0001$). The following graphs respectively show the correlation between the scores obtained in tasks 1 and 2 of the edugame and the PTSOT scores. On the basis of this data the percentiles were calculated. These are used as standard points for the edugame.

The data reported so far indicate the presence of a strong inverse correlation between the first task in the edugame and the results obtained by the participants in the PTSOT test. Hence, the first task of the edugame seems to partially measure the same abilities as those measured with the PTSOT test. The significant variation between the PT-SOT test and the MRT-A test confirm the difference between MR and PT, already stated in literature. Together with the intra-test reliability coefficients, these results support the hypothesis that the tests were correctly administered and that the participants completed the tests rigorously. The absence of correlation between the second and the third tasks in the edugame and PTSOT and MRT-A tests, leads to the conclusion that these two tasks do not measure the same abilities as the tests. Hence, they cannot be considered reliable to measure PT or MR. On the basis of these results, it was decided to go back to the design stage for the second and third tasks, whereas for the first task the results seem to be very encouraging. Therefore, the next testing phase concentrated solely on testing the first task among children.

3.2 Testing the first task of the edugame with children

The second step in testing the edugame aimed at exploring whether there were any correlations between the scores obtained in the edugame and the tests available in literature. Secondly, the testing also aimed at evaluating if the children would effectively be able to complete the task in the edugame and if the scoring obtained was suitable to provide a reliable measurement of the level of development of PT ability among children. The methodology adopted, therefore, was designed purposely to be able to establish a correlation between the results obtained in the edugame and the tests available for this age group. Taking into consideration the complexity related to the development of PT ability at this age (see paragraphs 3 and 4) and the scoring structure of the edugame, a paper-and-pencil test was compiled. Despite the fact that the tests used were extrapolated from tests available in literature and past national examinations, the use of these tests together has never been documented. The use of such tests addresses the need to verify if the first task of the edugame can actually measure the level of development of two different types of PT identified by Flavell and, eventually, also other more complex components that should be developed in this age range or beyond.

3.3 The paper-and-pencil test

The sequence of items used is composed of 8 tests, gradually increasing in difficulty. Figures 8 and 9 illustrate the first two test in this series that are the Three Mountains Test (Piaget, 1972) and a remodulation of it (Di Tore, 2014).

Figures 10 and 11 respectively report the third and fourth items in the test extrapolated from Flavell's Doll-Test.

Average PT Task 1	Average PT Task 2	Average PT Task 3	Average PT Tot
8.983606557	7.573770492	8.393442623	24.63114754
SD PT TASK 1	**SD PT TASK 2**	**SD PT TASK 3**	**SD PT Tot**
4.159989682	3.68135358	4.222249953	10.17467348

Table 1 - Edugame Scores.

Standard PTSOT	PTSOT SD	Standard MRT-A
24.53	14.9	11
Average score PTSOT	**PTSOT**	**Average score MRT-A**
79.34	44.83	6.33

Table 2 - PTSOT and MRT-A scores.

Cronbach's alpha PTSOT	**0.73884**
KR MRT-A	**0.67011**

Table 3 - MRT-A and PTSOT alpha coefficients.

Correlation	Edutask 1/PTSOT	Edutask 2/PTSOT	Edutask 3/PTSOT	Edutask Tot/PTSOT	MRT-A/PTSOT	Edutask3/MRT-A
R	-0.72	-0.42	-0.45	-0.61	-0.57	0.49
R^2	0.52	0.18	0.21	0.38	0.33	0.24

Table 4 – Correlations.

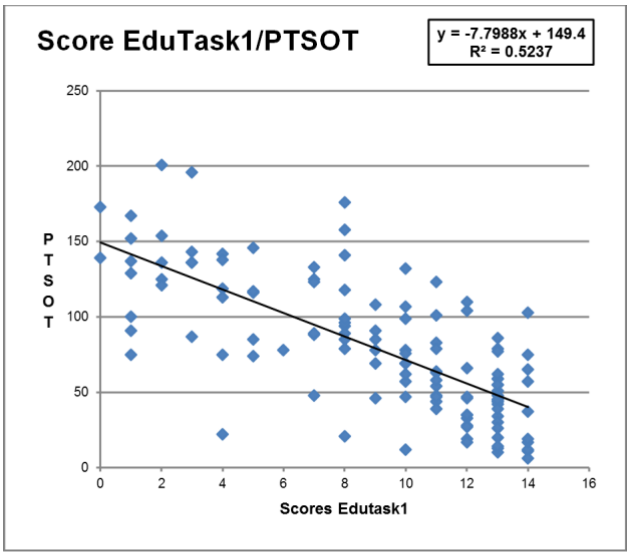

Figure 8 - Score EduTask1/PTSOT.

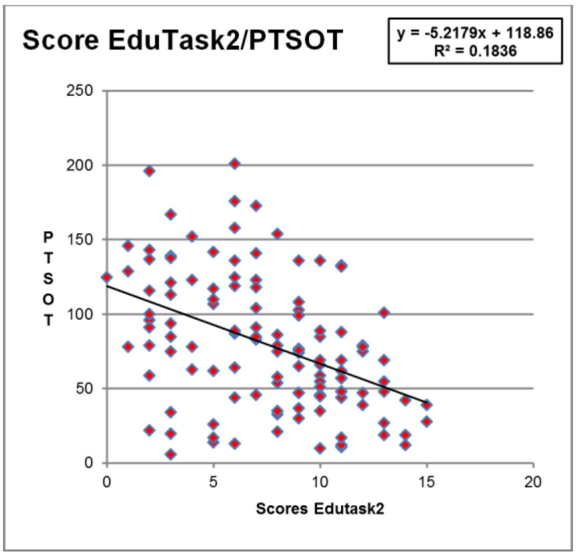

Figura 9 - Score EduTask2/PTSOT.

Figures 12 to 17 illustrate the tests extrapolated from national examinations (2012-2015) targeted for students aged between 7 and 13 years. The set of 8 tests was administered to the sample selected. The maximum number of correct responses was 9 since one test (Figure 14) included two questions. For every correct answer, one point was awarded. Wrong and unanswered responses weren't awarded any points.

The sample comprised 193 primary school pupils aged between 5 and 10 years. Both the edugame and the test were administered. The pupils were divided into three groups (5-6 years, 7-8 years, 9-10 years). The initial hypothesis was that the pupils:

- would have performed significantly differently both to the edugame and to the test on the basis of their age and gender;
- would have obtained correlated results both in the test and the edugame.

3.4 Data Analysis

Table 5 presents the descriptive statistics. The average scores and standard deviation are reported as a whole and per age group for both the paper-and-pencil test and Task 1 of the edugame.

Table 6 and Figures 18 and 19 present the disaggregated average scores based on gender and age.

The data illustrated seem to present different performances both in the test and task 1 of the edugame both in terms of gender and age. The only case where there is not an evident difference with regards to gender is the 9-10-year age group in the paper-and-pencil test. The internal coefficient of reliability of the scores obtained in the test (KR=0.74) ensures a satisfactory level of the internal coherence of the test. In order to normalize the data and identify an index able to comprehend not only the score but also the time taken to answer, the scores obtained in the test and the edugame were calculated using the following formula (Figure 20).

Where the:

- number of correct answers is given by the scores obtained;
- number of items is determined by the number of questions in the test (9 in the paper-and-pencil test, 15 in task 1 of the edugame).
- time available is the total time available to complete the test/task (1200 seconds for the paper-and-pencil test, 250 seconds in task 1 of the edugame)
- time taken is the time used by the child to answer each single item/question.

For example, considering a score of 4 points obtained in the Test Set with a total duration of 520 seconds, the normalised test score would be equal to:

$(4/9)*(1200-520)= 302.2$.

Similarly, considering a score of 6 points in the first task of the edugame, totalised in 164 seconds, the normalised score would be:

$(6/15)*(250-164)= 34.4$.

Successively, an ANOVA was conducted on the normalized scores, using age as a between factor. Both for the paper-and-pencil test and task 1 of the edugame, a statistically significant difference in performance in relation to age emerged ($p<0.001$). Tables 7 and 8 present the results for the paper-and-pencil test and task 1 of the edugame respectively.

A hypothesis test (T-test) was conducted to evalute the eventual presence of statistically significant differences in relation to the scores obtained by males and females in both the test and the task ($p= 0.0015$ and $p= 0.042$, respectively). In both cases statistically significant differences were present ($p<0.05$). The correlation index was calculated between the normalized points obtained in the test and the task ($R=0.62$) as illustrated in Table 9 and Figure 21.

4. Discussion

The correlation coefficient ($r=-0.72$) obtained from the scores attributed in the edugame and those obtained in the PTSOT test among adults appears to sustain the hypothesis that the edugame and the PTSOT partially measure the same cognitive ability (PT). Therefore, it seems plausible to sustain that the first task can be useful to assess the level of development of Pt ability in adults. As regards children aged between 5 and 10, the first task of the edugame also appears to be adequate to measure the development of PT ability both for level I and level II. In fact, on the basis of the data previously illustrated, the paper-and-pencil test used was in line with the initial hypotheses made. Indeed, the children participating in the study demonstrated different performances based on gender and age, as outlined in literature. It is also important to highlight that the activities related to level I PT ability were correctly answered by the vast majority of the children (87%), while the percentage of 5-year-olds that managed to answer correctly items testing level II PT ability was significantly lower (58%). These results are in line with the studies conducted by Flavell, conferring validity to the paper-and-pencil test used. The correlation coefficient obtained from the children's scores obtained in the paper-and-pencil test and in task 1 of the edugame ($r=0.6$) and the related tests carried out demonstrate the existence of a relation between the two tools used to measure the development of PT ability. The low R2 value may be interpreted as a non-linear correlation between the two series of data considered. Therefore, at this point, the linear model doesn't seem to be completely suitable to provide an explanation of

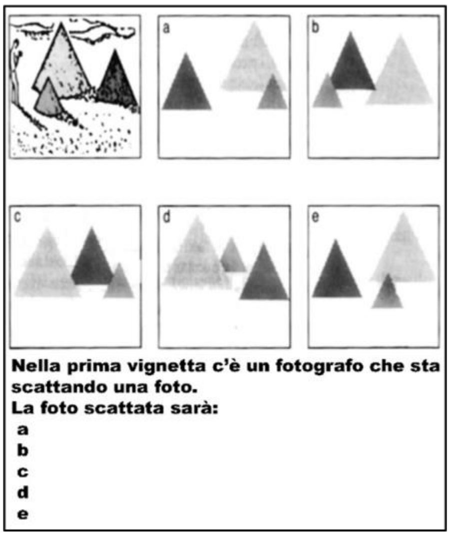

Figure 10 - Three Mountains Test.

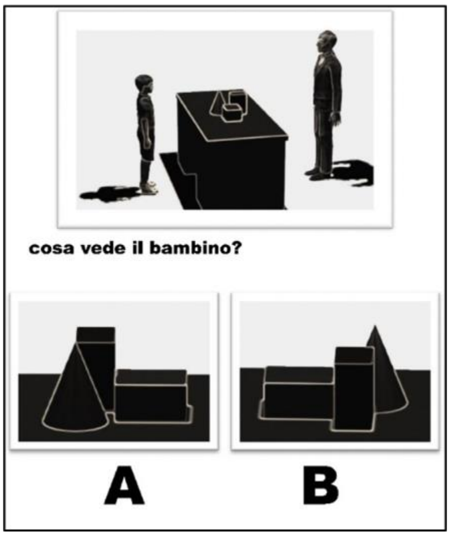

Figura 11 - Three Mountains Test revisited.

Figure 12 - Flavell's test revisited.

Figura 13 - Flavell's test revisited 2.

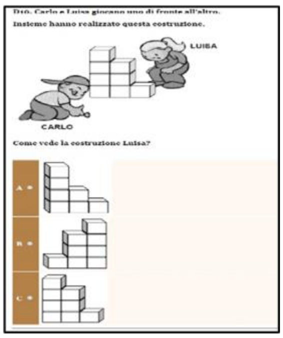

Figure 14 - Invalsi Test (primary School).

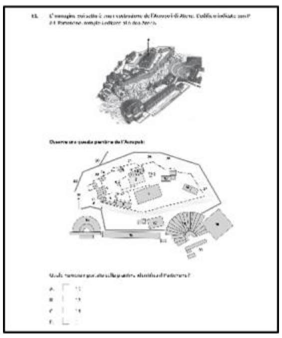

Figure 15 - Invalsi Test (first grade secondary school).

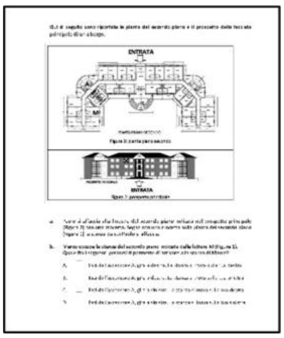

Figure 16 - Invalsi Test (high school).

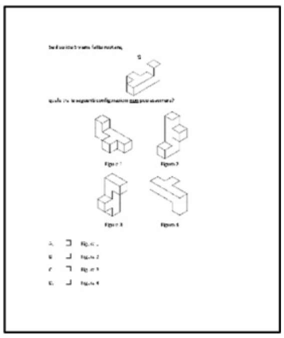

Figure 17 - Invalsi Test (high school).

	Average Score Test	Standard Deviation Test	Average Score EduTask1	Standard Deviation EduTask1
General	5.19	1.49	8.32	3.83
5\6 years	3.95	1.36	5.29	2.26
7\8 years	5.36	1.30	8.20	3.15
9\10 years	6.06	1.37	12.29	3.97

Table 5 - Descriptive Statistics.

		5\6 years		7\8 years		9\10 years		General	
		Test	Edutask1	Test	Edutask1	Test	Edutask1	Test	Edutask1
Female	**M**	3.70	4.61	4.95	7.27	6.07	11.71	4.80	7.28
	SD	1.40	2.04	1.28	3.06	1.44	4.07	1.52	3.71
Male	**M**	4.28	6.17	5.73	9.02	6.05	12.67	5.53	9.27
	SD	1.27	2.28	1.22	3.02	1.36	3.95	1.38	3.71

Table 6 - Disaggregated average scores based on gender and age.

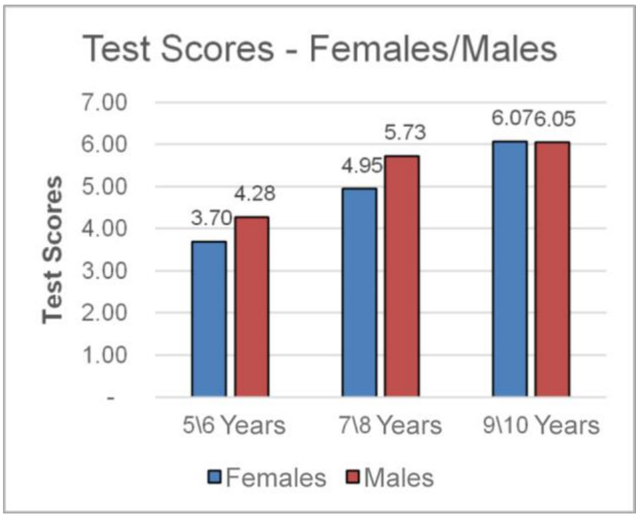

Figure 18 - Test Scores comparison - Females/Males.

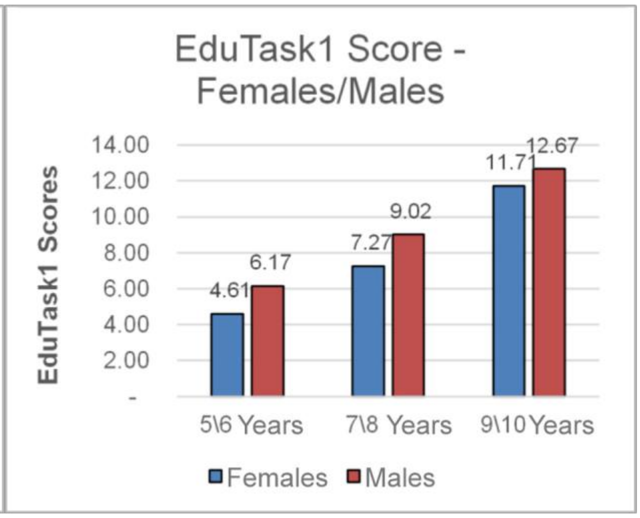

Figure 19 - Edugame first task score comparison (Male/Female).

$$\sum\left(\frac{\text{Correct answers}}{\text{Number of items}} * \frac{\text{Available time}}{\text{Used time}}\right)$$

Figure 20 - Formula used for calculating the score of the edugame.

Summary						
Group	*Count*	*Sum*	*Average*	*Variance*		
5\6 years	40	3,487.67	337.19	14,182.77		
7\8 years	116	2,129.00	449.39	11,998.55		
9\10 years	34	7,215.44	506.34	17,592.22		
Analysis of Variance (ANOVA)						
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between groups	579520.67	2	289760.34	21.55762708	3.76092E-09	3.04
Within groups	2513504.05	187	13441.20			
Total	3093024.72	189				

Table 7 - Data output ANOVA – Test Scores.

Summary						
Groups	*Count*	*Sum*	*Average*	*Variance*		
5\6 years	41	1,138.80	27.78	520.86		
7\8 years	117	5,455.33	46.63	833.54		
9\10 years	35	3,154.07	90.12	1,793.54		
Analysis of Variance						
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between groups	77858.00	2	38929.00	41.43576282	1.16295E-15	3.04
Within groups	178505.47	190	939.50			
Total	256363.47	192				

Table 8 - Data output ANOVA – EduTask1 Scores.

Regression Statistics		**ANOVA**					
R	0.62		*df*	*SS*	*MS*	*F*	*Significance F*
R squared	0.39	Regression	1	1228070.42	1228070.42	1.2E+02	5.0E-22
Adjusted R squared	0.38	Residual	191	1949675.04	10207.72		
Standard Error	101.03	Total	192	3177745.46			
Observations	193						

Table 9 - Analysis of Variance.

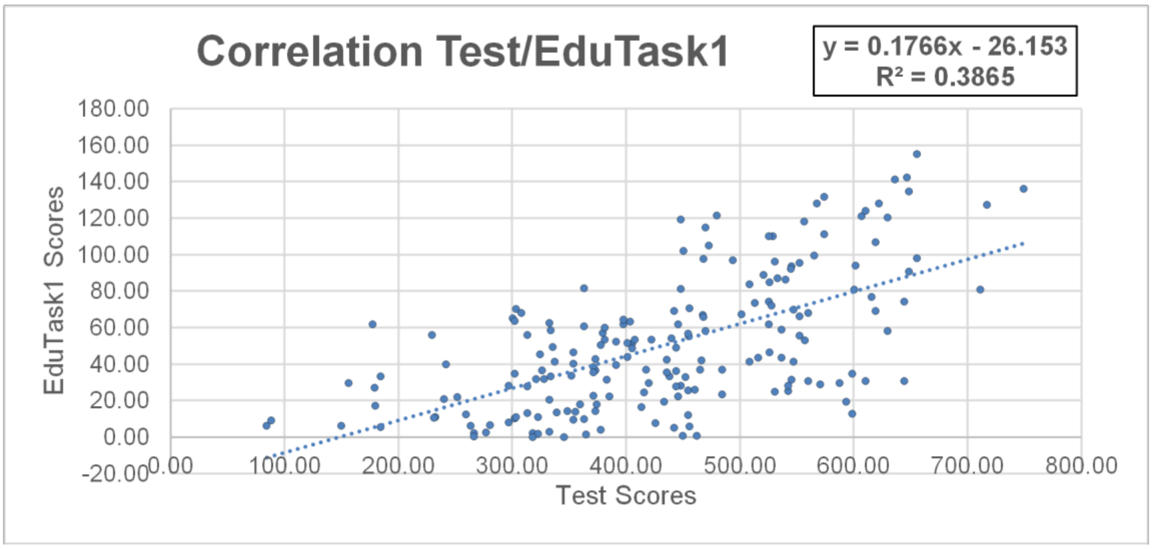

Figure 21 - Correlation Test/EduTask1.

the phenomenon being studied. Further studies will be conducted once the tests are administered to bigger samples of students in order to determine whether the inefficacy of this linear model is due to the inexistence of a non-linear correlation or because of the sample size. It is possible to sustain, however, that task 1 of the edugame is a reliable tool to measure level I and level II PT ability (as well as more complex components of PT) in childhood.

4.1 Conclusions and future perspectives

On the basis of the data collected, the first task of the edugame can be considered as a reliable tool for assessing the level of development of PT ability for children aged between 5 and 10 years. As regards the second and third tasks of the edugame, these are currently being redesigned. Successively, the same testing procedure will follow as for task 1. Future studies will examine the possibility of using task 1 of the edugame as a training tool to favour the development of PT for the age group considered. In relation to the design of a systematic teaching methods aimed at promoting the development of PT ability in primary school, one of the possible routes being explored is that of applying assessment protocols for the evaluation of PT that stem from studies conducted in the neuroscientific field.

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Qualitative Analysis of Digital Technology Research and Practice in the Field of Social and Human Sciences

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Abstract

This paper aims to present how the topic of digital technology has been discussed in the field of sciences, especially education. At first, presents 10 theoretical categories dedicated to the study of education in interface with digital technology, extracted from the systematic review of, approximately, 2,300 scientific papers collected in two portals: CAPES and ERIC. Following, the paper presents a topical research carried out in the Department of Social Sciences of the University of Rome La Sapienza, in particular on the Sostenibilia Research Center which integrates transdisciplinary research in the interface of social sciences, digital technologies, education and sustainability. In the scope of the research, Professors and Researchers were interviewed about which categories they identify as the main trend of study about digital technologies. After selecting the category of "The Study of Technology as a New Paradigm of Post-Modern Societies" two groups of possible answers were elaborated: the first one about why that category was chosen; and the second about what are the challenges in the study of digital technologies in the field of humanities. We offer some discussion and remarks about the characteristics of digital technologies' study among Education and Social Sciences' field underlighting the role of Open Educational Resources (OER) to consider a new paradigm for educational technology. Nevertheless, we present the concept of OER that connects education, its diverse skills and digital technologies.

KEYWORDS: Digital Technology, Social Change, Social Sciences, Humanities, Sostenibilia International Research Centre, Open Educational Resources (OER)

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1. Introduction

This position paper investigates how do the knowledge areas of Education Sciences and Digital Technologies interact within the academic sphere. The goal is to stablish 10 categories under which digital technologies are currently being studied inside university departments and how do the professors interact with the topic and connect different theoretical backgrounds to understand this contemporary phenomenon. As a result, alongside presenting the 10 categories this paper stablishes 10 reasons why digital technology is or isn´t a new paradigm in Education and 15 problems concerning digital technology studies among social sciences. After carefully data synthetization, it offers a discussion of how Open Educational Resources (OER) can help to foresee future *e*-ducation.

In the early 20th Century, studies regarding the concept of connectivity tried to understand how the system between man-message-technology was driven to comprehend what kind of materiality was present within the communication process. Many theoretical references have discussed communication materiality, arguing the human's emergence from a physical world to a symbolic one where everything (including messages and therefore algorithms) has a material

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content. According to Floridi (2014) there are three ages of human knowledge development: Pre-History, History and Hyper history.

In his work, he defines the Pre-History as the knowledge processes from the Bronze Age (stated by the development of writing in Mesopotamia and other world regions) until the Information Age (when begins the history period). Floridi suggests that both History and hyper history may appear as adverbs: they say how people live, but not when or where. Hence, the human development crossed those three periods as “Modes of Existence” (in a direct reference to the work of Etienne Souriau - Modes d´Existence, 2010, Presses Universitaire France).

Hyper history’s dependence on ICTs created the Information Cycle, as follows in Figure 1. Information is the nucleus (in direct reference to cells and molecules) orbited by procedures and stages, developing the idea of an information as a living organism that is not autonomous but can be recycled and managed.

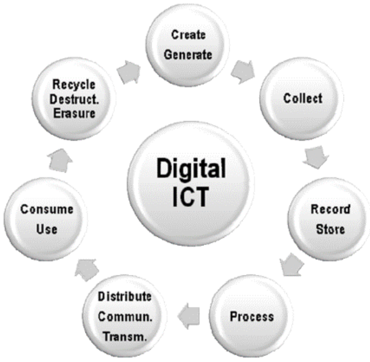

Figure 1 - The typical cycle of information in Digital ICT (Floridi, 2014, p. 5).

The idea of information as a living process encompasses the concept of Complexity supported by Morin (2015) as a term that refers to the incapacity to define simplicity and totality. Complex Thinking can be described as multidimensional with heterogeneous associations within the surrounding phenomena. It is the reintegration, or aggregation as Bruno Latour would argue (2005), between anthropocentric and exosystemic thinking highlighting the unbalanced dynamic as a power source to action. These procedures are, according to Morin (2015), the living being’s logic (the variation between order and disorder) which is what the author calls auto-eco-organized organism. In other words, an organism is capable of following existing associations and creating new ones (a direct reference to Aristotle’s conception of “autopoiesis”).

Insofar as Morin clarifies the concept of Complexity, he introduces his perspective over the expression of “systemic”, defining it as several integrated parts that creates clusters or groups, highlighting the frontiers and boundaries between those clusters. However, he states that the overall being is larger than the sum of its parts. Here, what is important in a systemic environment are not the entities alone but their connections, so the simple number of stakeholders does not reveal much if they are not connected in an integrated system.

In Human Computer Interaction (HCI) ICTs create and facilitate the communication between users and computational systems. To mention ICT is possibly to reconsider that computers do not compute, and telephones do not make calls. Humans do all these actions, or at least until autonomous algorithms begin. Those systems deal with data and we humans trust in their capacity to assess them, as we are not able to do so due to the high quantities involved (or Big Data and Network Dynamics).

To be in a network is, according to Latour (2005), to be an active entity playing a role. What does not move or make any actions does not exist in a network, which confounds some of the attempts to describe a network as a complex photography. A network could not be a steady image as it changes on a moment-by-moment basis. Plus, the network represents controversial dynamics in which the number of stakeholder’s associations are increased requiring high performance equipment to track its agency (Venturini, 2010). In other words: to understand technology, the first step is to consider that networks are not steady and linear, but complex and highly dynamic.

Discourse surrounding network dynamics in Communication is so complex that it is often necessary to borrow terminology from other fields to explain the subject in a more coherent manner. Theorists regularly use the concept of Ecology to describe the Communication field (as “Communication Ecology”) due to a possible unavailability of terms to describe the process regarding digital technologies.

Within Ecology is possible to analyze new forms of action that we cannot define as social or as a result of communicative and technological conditioning (Bonami & Nemorin, 2020). Their protagonists are not only humans, also other stakeholders who contribute to build a complex network: the action, then, is the result of synergistic interactions of individuals, information circuit, devices, digital social networks, sensors, data, platforms (Accoto, 2017, 2018). Ecology sets up a concept from the Greek *oikos*- space (Di Felice, 2017), and *logos*- word, which does not define a contrast, but rather a connective net-like structure, representative of society and of the assumed social action.

2. Material and Methods

Sostenibilia is an International Transdisciplinary Research Centre found within the Communication and

Social Research Department at Sapienza University, Rome. Its origin was motivated by the demand for integration between the Communication, Social Sciences, Environmental Sciences and Digital Technology fields.

Sostenibilia has as a goal to search for interpretations and theories that may contribute to the expansion of societal ideas, thus stimulating the international debate around climate, education and technology prospects of the 21st Century. It is considered an interesting case study as there are a growing number of institutions, research groups and academic networks acknowledging a social perspective in the phenomena of digitalization analysis. Their specificity is in promoting a methodology that makes use of sociological analysis that can ease the transdisciplinary examination of ecology complexity.

To begin, the present research aims to understand which theoretical references are being used to study technology. Through this perspective, academics were interviewed and their answers to two questions were studied: "*Why is technology a new paradigm of postmodern societies*?" and "*What are the main problems concerning digital technology studies within the Social Science and Humanities fields*?". Those questions were built on a theoretical background, to be presented next.

We tried to analyze the conceptions, opinions and references concerning the study of digital technology in the social sciences field. For this, interviews were conducted with scholars and researchers from four different theoretical areas: Media and Technology, Education and Technology, Technology Epistemology and new trends in the study of Technology. The eligibility criteria for interviews were based on the prominence of their work inside the Department of Communication and Social Research at Sapienza University of Rome.

This article considers that digital technology can be studied under ten categories. These categories were extracted from database research concerning the reading of 53 articles regarding the themes of Social Sciences, Education and Technology from 2016 to 2018 (the "relevant period"). We explored the procedures of search and selection, followed by the papers' systematic review. Each of the 53 articles were placed in one of the categories in the following table. It is important to note that these categories are common topics presented by papers and express a theoretical background to embed the present discussion.

The first database accessed was the Scientific Papers Portal by Coordenação de Aperfeiçoamento de Ensino Superior - CAPES (by Ministry of Science and Technology in Brazil). The keywords (in Portuguese and Spanish) used (in intersection) were: "superior education", "digital technology", "transliteracy", "literacy", "information", and "network". There were 1,530 results, of which 763 had been peer reviewed and 279 of these published within the relevant period. Following reviewing the abstracts of each of the 279, 23 articles were selected as part of the systematic review. The second database was the Education Resources Information Centre (ERIC) sponsored by the Ministry of Education in the United States. The keywords (in English and in intersection) were "superior education", "digital technology", "transliteracy", "literacy", "information", and "network". As a result, 44,788 articles, of which 24,947 had been peer reviewed and of these 5,936 had been published after 2015. Of these 5,936, 1,971 had the text available for download. Following reading the abstracts of each of the 1,971, 30 articles were selected as part of the systematic review.

Methodological procedures are consisted of the following stages: (i) scientific database research; (ii) systematic review of database findings; (iii) scientific overview of topics and categories; (iv) selection of academics; (v) semi-structured interviews; and (vi) coding interview findings (coding here refers to extract, analyze and categorize theoretical elements from the paper collection).

Polanin, Maynard and Dellsaint (2017) characterizes the overview as a close form to systematic review, but the information extracted is often quite different, as the content of revision can reach theoretical levels. The overview codes and reports pertinent information regarding the systematic review in addition to information on its reports about the primary studies. As a conclusion in this paper, the overview offers ten theoretical categories and the ten main problems within Digital Technology studies in the Applied Social Sciences field.

We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) which consists of an evidence-based set of items extracted from a large set of references collected from relevant literature. PRISMA is predominantly used in healthcare sciences but can be applied in this research as an effective way to evaluate the data collection through theoretical review and interviews. It has contributed to the systemic reviews sciences and can be transferred to any theoretical ground as long as it meets the criteria to apply the procedure.

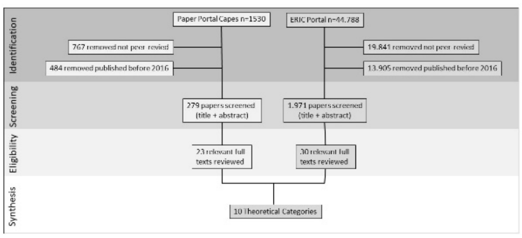

Figure 2 - PRISMA model appliance.

The first criterion was chronological: theoretical research (database collection) was restricted to production between 2016 and 2018 while the interviews were collected in 2019 (following the requirements of peer-reviewed materials and credited sources). Regarding the data base research, the criteria are as follows:

- have a significant contribution to the discussion of Education and Digital Technology;
- provide different perspectives and practical reports of initiatives occurring in cross national reports; and
- engage in a discussion about media, information literacy and digital literacy in a specific period considering the level of development of the digital technologies applied in Education (this criterion was considered desirable, but was not required).

The selected studies were coded comprising the following sections: (a) bibliographic information; (b) overview of characteristics and methods; (c) thematic synthesis; and (d) main questions asked and answered by the study.

Regarding the interviews, the eligibility criteria are listed as follows:

- be an Associate Professor or Research Collaborator at Sapienza University of Rome within the Department of Communication and Social Research;
- have a scientific production about digital technology or transmedia in the Social Research Department; and
- engage in a theoretical discussion about media, information literacy and digital literacy (this criterion was considered desirable, but was not required).

For that matter, it was elaborated an interview script to guide the data collection. The script considered to investigate theoretical references and opinions.

3. Results

The choice of categories was directed by the systematic review. Their goal is to understand how the selected papers studied and dealt with Education and Social Sciences Fields interfacing with Digital Technologies. Some important considerations:

Categories were extracted following current topics discussed during the systematic review and can be found on Table 2.

After elaborating them, each analyzed paper was fit under one or more categories; and Table 3 summarizes the categories and defines them according to the systematic review.

#	**Interview Script**
1	How would you define digital technology? What are the main theoretical references you use to study and teach about the subject?
2	Why do you consider digital technology as a new paradigm in the knowledge society?
3	What are the main problems when considering technology studies and practices?

Table 1 - Interview script.

Conceptual categories extracted from the systematic review of 53 scientific papers selected among ERIC and CAPES databases
The Study of Technology as a Potentially Empowerment to Solve Problems
The Study of Technology as a Logical Operation
The Study of Technology as a Tool
The Study of Technology as a New Paradigm of Post-Modern Societies
The Study of Technology as a New Paradigm of Education
The Study of Technology as a Human Perceptive Extension
The Study of Technic regarded as an autonomous entity (Big Data, AI, Blockchain, IoT)
The Study of Technology under an ecological approach
Technology under a Distributed Narrative
Technology under a Humancentric Narrative

Table 2 - Theoretical categories extracted from the systematic review of 53 scientific papers.

Exploring the theoretical categories	
Theoretical Category	*Description*
The Study of Technology as a Potentially Empowerment to Solve Problems	Presents digital technology as the students' and educators' empowerment accelerator, enabling improvement in digital skills. The word "potentially" is followed by the word "possibility", as digital technology provides new opportunities.
The Study of Technology as a Logical Operation	Deals with digital technology as logical skills and knowledge groups, next to language learning, empowering the individual to develop this ability.
The Study of Technology as a Tool	Interprets digital technology as a tool, instrument or as a means to an end. Deals therefore with technology as an object to be demanded by a human to reach personal, professional and cultural goals.
The Study of Technology as a New Paradigm of Post-Modern Societies	Offers digital technology's interpretation as a new society paradigm, promoting: • the dissolution of the industrial economic background; • the age of platform society (Dijck, Poell & Waal, 2018); • the urban gentrification with new arrangements brought by platforms; and • the data culture suggested by Hyperhistory.
The Study of Technology as a New Paradigm of Education	Interprets digital technology as a new educational paradigm, promoting the hybrid learning between: • the classic teaching (instruction); • the analogical knowledge dissemination (like books); • personalized learning; • open educational resources; • project based learning; and • knowledge shared production.
The Study of Technology as a Human Perceptive Extension	Presents digital technology based on Marshall McLuhan (1964) studies about the extension of a human, which cannot define its use as a means to an end as the human alters himself when in contact with it.
The Study of Technic regarded as an autonomous entity (Big Data, AI, Blockchain, IoT)	Interprets the technic as an autonomous entity capable of creating and reproducing knowledge and information, arguing against the human as the only entity capable of intelligence.
Study of digital technology under an ecological approach	Considers technology as far more involving than its aspects surrounding the human context taking into consideration the life history, environment and sustainability narrative, based on the ecology as an entropy concept.
Technology under a Distributed Narrative	Describes the interactions between humans and non-humans under a flat ontology (based on the Network-Actor Theory by Bruno Latour (2005) where the human is not the only one to dominate the technic. As a matter of fact, the agent's nature is not important, but its actions and how they aggregate with other agents are.
Technology under a Humancentric Narrative	Describes the interactions between humans and the technic underlying the human relevance in digital manipulation. This entitles the human to create, alter, transform and share the technical phenomena. Expands the technic as something demanded to reach a goal. The resource manipulation comes from an industrial (or historic) perspective while the globe has reached Hyperhistory.

Table 3 - Exploring theoretical categories to study digital technology and education.

Based on data base research, category design, and conducted interviews, we were able to elaborate two main outcome groups by answering two questions: "why technology is a new paradigm of postmodern societies?" and "what are the main problems related to digital technology studies among the Social Sciences and Humanities Field?".

These two groups are a collection of answers retrieved from the interviews and are organized in following Tables 4 and 5.

Group of answers 1	
#	**Why technology is a new paradigm of postmodern societies?**
1	Reshapes the economic regulation and background
2	Empowers people in a symbolic and cognitive way
3	Information (especially personal) becomes a powerful asset
4	There is a new perception of what kind of government people need
5	Remodels the way people populate cities, build the cultural background and product knowledge
6	Industry dissolution provides new ways to know and learn as a distributive intelligence
7	It isn't yet a new paradigm, as it doesn't have all the elements to build and evaluate a new paradigm. However, digital technology is bringing the need for a new paradigm in education and OER seems to be the key to this.
8	Technology is a powerful actor/stakeholder not a passive tool. Its own will also became autonomous. Like a doll or a toy that comes to life.
9	The basic dimensions of digital technology suggest considering them as strategic tools for the constructions of new forms of social spaces and relations and not directly a new paradigm.
10	Thanks to the new temporal, spatial, and network forms enabled by digital technologies, the morphology of society is changing and, thus its own composition: you can just think that nonhuman subjects have a growing social position and role.

Table 4 - First group of answers.

Group of answers 2	
#	**What are the main problems concerning digital technology studies among the Social Sciences and Humanities Field?**
1	TIMING: the timing of technological transformation is much faster than the time taken to adapt to it. This delay is related to mediation, as citizens begin to enter the Platform Society rethinking social standards.
2	PARADOX: the time required to understand technology is too long COMPARED to the short time taken to adapt to it.
3	GENERATION: how youth use technology, how they understand and perform their activities.
4	MACRO & MICRO: [macro] to capacitate teachers with soft and not only digital skills; [micro] how to connect and encourage professors to be interested?
5	MENTALITY: educators and institutions that stands in the way of digital technology promotion.
6	HUMANS & NON-HUMANS: the social created by technology is composed of humans and non-human entities.
7	BLACK-BOX: technology is a black-box in education where professionals may feel harmed or unprepared to deal with it.
8	"AND" & "AS": why technology AND education AND social? Why not technology AS education or AS social?
9	PUBLIC ENGAGEMENT: lack of connection between the academic context and civil society. University projects are important but not enough.
10	MATERIALITY: people have a hard time understanding what technology is because they cannot see its materiality (can't touch it).
11	DYSTOPIAN: technology should not be viewed as a dystopian and abstract background that may or may not come true (this is a futuristic narrative from the 1950s).
12	METHODOLOGICAL: technology is no longer a tool or method that was created to meet human demands (this is a functionalist narrative from the 1980s)
13	LEGITIMACY: the social sciences still use traditional paradigm to interpret current social processes. The information can be produced by everyone, thanks to handhelds such as smartphone. The authority of a journalist, as well as that of a scientist in regard to the result of scientific research, is no longer important for the legitimation of the truth.
14	TRANSFORMATION: these cases, which are both daily practices and objects of social studies, show that, considering a problem, the result of the transformation of society is the result of the interpretation of the current processes with past models: innovation always produces its own analytical tools, as well as lifestyle.
15	PRODUCTION: today, the consumer is increasingly a prosumer: humans don't need to buy a song (e.g.). They can produce with an app or a software and achieve their goals with many software and hardware operations.

Table 5 - Second group of answers.

4. Discussion and Conclusions

This paper brings two groups of answers for the questions: "why technology is a new paradigm of postmodern societies?" and "what are the main problems concerning digital technology studies among the Social Sciences and Humanities Field?". About the findings, it offers 10 reasons why digital technology is (or isn't) a new paradigm in postmodern society and 15 problems of digital technology studies in the social field. Regarding the results, there are at least two possible paths for discussion: social and educational.

In the first path, Nocenzi and Sannella (2018) explains that the sociological scenario, in terms of methodologies and theories' reformulation and for social research, shows some transformations promoted by digital technologies. The uncertainty of science has strengthened this process while its authority as a source of knowledge has been delegitimized. Even what could seem like a paradox in the face of the growing specialization of technological knowledge, a popular wisdom prevails as a result of statements, thoughts, proposals that users can express using social media and a worldwide connection.

These changes are challenging for the social sciences as they must re-formulate their own basic concepts, methodologies and even theories. However, the adoption of technologies in everyday life requires an analytical function that social sciences can provide as a structured field. Education is one of the strategy fields of Social Sciences and structural changes we foresee are challenging for educators and students. One of them, is the process of legitimizing knowledge and the growing dispute between knowledge itself and wisdom (Puech, 2016).

In the current interpretation it is risky to define who can verify the outcomes of this common debate, avoiding falsification and mistakes, both in good and in bad faith. Thus, education as technology and information should guide its activities in order to promote logical learning and citizenship empowerment, viewing digital as an extension of the human being. Nevertheless, educational approaches often consider the digital technology approach vis a vis an instrumentalist bias, a factor that this research intents to refute (at least the Aristotle-based instrumentalist perspective). On the path of logical learning, the concept of Media and Information Literacy offers an overview that understands the needs of 21st century's students and educators (Passarelli & Angeluci, 2018).

One of the applications of educational technology is through neuroscience. The usefulness of its findings for research in education is an ongoing debate. Ng & Ong (2018) talks about a gap between what you know about the human brain and what makes it able to be bridged by these neuroscience findings. However, research results normally found in small dimensions cannot be generalized. In addition, there is a demand for neuroscientific research in schools and universities, but it is not very clear how neuroscience can connect theory and practice.

First, neuroscience research has explored the representation and processing of syntactic categories. Some procedures such as MRI are used to observe how the brain moves and reacts to the learning of some items. Reading some research findings, we learned that some results on students' brain observation using digital technology reveal the activation of regions of the cortex that are equivalent to areas of language learning. A similar cortex indicator is perceived when producing and accessing materials, reason why Ng & Ong (2018) bring the importance of OER to further discussions related to neuroscience.

Just as Ng & Ong (2018) addresses the applicability of neuroscience in teaching, providing free access materials can be substantial to bridge the gap between theory and practice. OER have a particular role in that since not only enables the access but the broad production of materials that can highlight both educator and student activities.

In 2002, the term Open Educational Resources was coined by UNESCO (2017, 2019) to refer to educational resources generated for the provision of digital access through Information and Communication Technologies (ICT), to be used for non-profit purposes, following the Open Access guidelines. The OER theme has broad similarity with the concept of Open Courses (Open Course Ware - OCW) defined as an open and free high-quality digital publication for higher education. The William and Flora Hewlett Foundation defines OER as resources for teaching, learning and research that reside in the public domain or have been made available under a license that protects intellectual property and allows its use as free, shared and generative. OER has more than the potential of its devices and content: it has a transformative power based on network and sharing dynamics.

Importantly, UNESCO (2017) recognizes that continued refinement of an emerging set of indicators and survey items is necessary, and requires that they be pilot tested in several countries and scrutinized against a set of core criteria that address:

1. Data availability, in terms of a government's ability to gather reliable data on the indicator; and
2. Global comparability, in terms of the usefulness of the indicators for making global comparisons.

Key indicators can be listed to assess the OER development in cross-country and regional analysis and should be considered in the discussion of OER driving endeavors to a new paradigm of education:

1. Proportion of countries that have OER and how they report their contribution;

2. Ways and reasons why the country is engaged in OER by type of initiative;
3. Types of barriers to mainstreaming OER: language, digital access and cultural barriers;
4. Skills required to improve OER use by educators and learners;
5. Barriers to engaging educators in the production of OER;
6. Types of OER content produced by educators and license used for resources produced by educators;
7. Perceived impact and benefits of OER on teachers, instructors and for students;
8. Inter-institutional activities around OER; and
9. Co-operation with other educational institutions for exchanging OER.

Yet, indicators could foresee the digital transformation among societies or at least understand how OER is being applied. Important to consider that technology has at least four influences on education: methods transformation; content reshaping; institutional structure transformation; and relationship redefinition. Premature digital developments in the 1990s had an influence on one, two or three of these areas. However, for a paradigm shift to occur, the four topics need to be transformed. Paradigmatic transition involves changing basic concepts that underpin a discipline or field of knowledge and unless the four influences are combined, OER won´t bridge that transition.

The new logics of knowledge production at the interface with a range of hybrid methodological procedures give rise to the third paradigm of education. The first paradigm existed for thousands of years and operated in a pre-technology era. It was the one-to-one tutoring and mentoring format. The second emerged with the advent of analog media, especially with books printed in the Middle Ages. It is a one-to-many teaching model. This model is less effective than direct mentoring because the pupils' response process was more subjective. On the other hand, the paradigm shift to one-to-many enabled education to develop as common good to society until the 20th century when was considered a human right by the Human Rights Universal Declaration in 1948.

One may argue that education is at the dawn of its third paradigm. This affirmation is defined by the connection between students and teachers and the characteristics of many-to-many and multi-directional mentoring. The teacher no longer holds the role of the great master of knowledge. Furthermore, they are mentors or guides and students are involved in a process of sharing knowledge and exploring discovery. This paradigm represents the decline of the teaching hierarchy, the end of courses, when teaching becomes barrier-free and disciplines communicate (Passarelli & Gomes, 2020). OER is an important connector in this scenario, since encourages a horizontal relationship between educators, learners and resources.

The arrival of the third paradigm does not condemn the end of the other two, just as the arrival of the second did not expel the first. However, they are set aside, although they are still considered important. In this way, hybrid teaching assumes a certain role in which hybrid courses combine traditional instructional models and online learning. For example, the COVID-19 pandemic brought a new perspective on education with the compulsory measure of social isolation in many countries to avoid the virus spread and contamination. Reports from United Nations, OECD, World Bank drive the discussion if, after the pandemic is contained, education will go back to be completely presential or if it will incorporate novel methodologies learned through the past four months.

Some underpinnings for educational innovation based on this emerging paradigm could include the following: first, educators could build and incorporate digital resources into teaching at any level and field of knowledge, while combining methods with digital and connective media creating a communicative sphere in the learning community. Second, students can become lifelong learners and, eventually, teachers. The line between teacher and student is tenuous and can be dissolved, where teachers are guides and students are participants. Third, ethics must be the common compass that guides teaching in the Digital Information Age. Experienced educators can play vital roles in fueling the development of this moral compass in students. Fourth, it is important to avoid falling into technological determinism. Technology, no matter how advanced, does not guarantee a better education, just as it is not the solution for everything. Still, it is worth noting the promise of an engaged community of apprentices for life, an objective which requires a collective effort.

On this subject, Floridi points out that *e*-ducation (as he calls it) is coupled with knowledge and, as the information society testify the challenging growth of data, there is a demanding to understand which structures underlie learning processes. According to him, the learning mind architectures is pretty similar to the logic of algorithms, reason why these processes should have a better dialogue between their fields. Education basic structure should be so the join architecture of knowledge, insipience, uncertainty and ignorance and the real question is not “how” to teach the next generation, but “what”.

Future *e*-ducation must cross the mind’s categories borders and follow a transdisciplinary path to realize a complex understanding of surrounding world. As Floridi mentions, the “science changes our understanding in two fundamental ways: about the world and about ourselves” (2014, p. 87). Science compiled with education may be the key to understand how OER is developed within digital prospects.

Today, thinking about teaching is not only considering the interface between teacher and student: it is to understand that the words assigned in this process carry meanings that can mask technology and the collective construction of knowledge. Just as the prefix “post” is used to revoke categories of humanism, or the term “hybridism” to address the controversial aggregations of indistinct entities, the expressions “literacy” and “education” lack a “post”-look at their meanings. Their rigid senses lead to the denotation of instrumental processes of world apprehension, leaving the connective extension of the subject as a subjective factor and not the main objective.

OER is built within transdisciplinary and we refer the “trans” prefix according to Latour’s “translation” definition, recognizing Education as an informative architecture (cohort of structures, references and conceptions that support a knowledge field – Edgar Morin, 2015) that favors the multiplication of hybrids, presenting itself as the basis of knowledge.

“What is called 'knowledge' cannot be defined without understanding what knowledge acquisition means. In other words, 'knowledge' is not something that can be described by itself or as opposed to 'ignorance' or 'belief', but only by examining an entire cycle of accumulation” (LATOUR, 2011, p. 343)

The challenge of pursuing research in this course of thought is to align academic elaborations with the pragmatical context (primary schools, high schools and other educational levels) and empower both population and government to understand the implications of what appear to be a new possibility for the philosophy of knowledge and, if not yet a new paradigm, a vision of a changing reality.

List of abbreviation

Abbreviations	Definitions
ICT	Information and Communication Technologies
AI	Artificial Intelligence
HCI	Human Computer Interaction
IOT	Internet of Things
CAPES	Coordenação de Aperfeiçoamento de Ensino Superior
ERIC	Education Resources Information Centre
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
MIL	Media and Information Literacy
MRI	Magnetic Resonance Imaging
OCW	Open Course Ware
OER	Open Educational Resources
UNESCO	United Nations for Educational, Scientific and Cultural Organization

Datasets and reproducibility

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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