Bebras Contest and Digital Competence Assessment:
Analysis of Frameworks

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ABSTRACT

The article is made of two parts. The first part discusses the importance of informal education environments supported by IT/ICT in students' learning, followed by reports of some international competitions and the role they have in improving students' interest and use of Informatics and related disciplines. At the end of the section, it describes the Bebras contest, an international competition supporting students' Information and Communication Technology competences with emphasis on cross discipline competences, which are useful to solve real life problems. In the second part of the article, the outcomes of a research study on the features of a framework for digital competence assessment are reported. Based on this, some criticisms emerging from the analysis of the answers that students gave to a questionnaire built on the guidelines of the mentioned framework are analysed. They are integrated by the comments that teachers, colleagues and researchers made on the structure of the hypothesized framework. At last, a new model for digital literacy assessment is proposed. In the conclusion, the necessary elements for making the last framework effective are outlined and its suitability for the construction of the yearly questionnaire of the Bebras contest is discussed.

Keywords: Digital Competence, Digital Literacy, Evaluation and Assessment, International Contest, IT/ICT

INTRODUCTION

Information Technologies (IT) and Information and Communication Technologies (ICT) have produced many changes in our society and especially in students' learning; new technologies greatly increased the influence of informal learning on students approach to knowledge construction and made

deeper the difference between what they learn at school and what they learn outside it. The above phenomenon is not limited to students, it can be recognized in every kind of people and more generally in firms, corporate and whole organizations; it can be considered an integral part of the transformation process affecting our society, where the role and the importance of non formal and informal educational environments in people's knowledge development is continuously growing and in many cases has overcome formal contexts.

It can be easily recognized that the problem is not with technology but in their use (i.e., computers, laptops, mobile phones etc. are the same in whatever context people use them); process management, process organization and people involvement in the phenomena where IT/ICT play a relevant role are in fact responsible for the described changes. As an example the case of school and extra-school experiences are described in what follows: different topics, tools and strategies have been used in formal education to develop students' computing skills and let people autonomously interact with automatic systems to solve problems, create documents, communicate and, more generally, make with computers what they did in a different way (i.e., to digitally manage information being conscious of the operations they carried out). Outside school, edutainment tools and computer games created special environments where people usually learn by immersion and interaction with a virtual context. Edutainment is a form of entertainment designed to educate as well as to amuse. It typically seeks to instruct or socialize its audience by embedding lessons in some familiar form of entertainment. Otherwise stated virtual environments, simulation contexts, educational games as well as computer games have been and still are an important part of people's life and modern education and they are also responsible for the development of computing skills. The success of these last experiences is usually attributed to the motivation people have in the interaction with digital media and the corresponding tools and in the feedback they have from them (Vasilyeva, 2007).

Many questions are connected to the above issues:

- First, are the reasons for the reported changes the consequence of the natural evolution of society?
- Second, how much the above changes are influenced by the approach people have with technology at school and outside it?
- Third, are there strategies helping students, their families and teachers develop and use common IT/ICT based teaching-learning processes?

In what follows an attempt is made to answer the above questions and two different kinds of experiences are discussed: first, the features of the "Bebras" (beaver) International Contest

on Informatics and Computer Fluency are described, second, the analysis of digital literacy and the development of frameworks for digital competence assessment are analyzed.

BEBRAS INTERNATIONAL CONTEST AND DIGITAL LITERACY

Since many years different multimedia and edutainment tools have been developed to help young people to improve their thinking skills. Furthermore many instruments have been planned to find students with good mathematical and computing skills and let them develop their natural talent. Problem solving has been the main principle underlying those experiences, because it was considered the best way to develop thinking skills. On this side the Olympiads of Mathematics (http://www.imo-official.org/), the Olympiads of Informatics (http://ioinformatics.org/index.shtml), the Kangaroo competition (http://www.mathkangaroo.org/) and other international contests had a great role since they started, because they involved many thousands of young students all over the world.

More recently V. Dagiene and her colleagues developed the idea of a new contest in IT/ICT, devoted to school students (http://www.bebras.org). The basic ideas underpinning the new contest were:

a. Interest and engagement are very important in problem solving (Dagiene, 2006; Dagiene & Skupiene, 2004),

b. Problem solving is the individual capacity of using cognitive processes to compare and solve real, cross-disciplinary situations where the solution path is not immediately obvious (Casey, 1997).

As reported by V. Dagiene the activity of beavers on trees' branches and strands was so noticeable, that the beaver was suggested as symbol and name of the contest, therefore the word "Bebras" (the Lithuanian word for beaver) has been used for the name of the contest.

One could ask for the reasons of one more competition, but the main answer to this question comes from the organizing committee of the contest, who stated that cognitive, social, cultural and cross-cultural aspects are very important in the use of technology. Otherwise stated these aspects had to be clear in the minds of those who prepared the questions so that the competition had to focus on the following aspects:

• put strong emphasis on the influence of IT/ICT on culture and language,

• help educational community to support school students who can use IT in most creative and profound way,

• develop students' ability to derive pleasure and satisfaction through intellectual life while thinking about efficient and effective use of

applications of IT/ICT in everyday experience.

The main principles for the structure of the "Beaver" contest have been borrowed from the international mathematical contest "Kangaroo". Since the first contest, in 2004, it does not restrict participation, so that everyone who is willing can participate. The main goal of the contest is to evoke interest in larger and larger numbers of students around the world.

The rules of the "Beaver" contest are very simple:

a. The contest takes place in every country during the same time period,
b. There exists a common problem set that is translated into the different native languages,
c. The time limit for answering the whole questionnaire is fixed and the format of every question is closed and structured as interactive task or multiple-choice test.

The students taking part in the contest are grouped into three age groups called: Benjamins (primary school students, i.e., pupils), Juniors (students with some IT/ICT basic knowledge) and Seniors (upper secondary school students). The age of the students' groups was progressively adjusted to consider the differences in the national school systems and the increase in the number of the countries and students taking part in the contest. During the contest, each

participant has 45-60 minutes to solve 18-27 problems of various complexity and different scores (i.e., time allocation and number of problems depends on countries). The problems are distributed on the following three different score values: 3 points, 4 points and 5 points. Students answers are evaluated as follows:

• when they are correct they add as many points as specified to the total amount,
• when they are wrong they diminish the total amount of 25% of the given points (i.e. − 0,75, − 1, and − 1,25 points, respectively),
• when not given (unanswered), they do not add or subtract any point to the total amount (i.e., 0 points are given).

To avoid negative results, each participant starts with the amount of points equal to the total number of the questions (e.g., 18 points if 18 questions are given).

As can be easily deduced the choice of the problems to submit to the students requires much more attention, because interest and engagement are very important in problem solving. It is well known, in fact, that most part of the textbooks and teaching materials used by the students in their class-work and at home do not propose problems but in the best cases they offer just exercises. When teaching computer programming and more generally IT/ICT via problem solving, it is very important to

choose interesting tasks (problems) to motivate students in the search of possible solution/s. Therefore, one should try to present problems from various spheres of science and life, as close as possible to real life and with suitably chosen situations.

Problems can be of different types, starting from the most common questions on IT/ICT and their applications in everyday life or including specific integrated problems related to history, languages, arts, and, of course, mathematics. It is also very important to choose the problems so that the participants in the competition are not influenced by the operating systems or the computer programs they are experienced with.

At the second international Bebras workshop, a brainstorming session was held to generate ideas for different types of tasks that could be used in the contest. Also the classification of tasks was started and some topics groups were suggested (Opmanis *et al.*, 2006).

The work on problem classification continued in next Bebras workshops and in discussions between the members of the Bebras Organizing Committee. In September 2007, some active members of the Committee during the meeting in Potsdam proposed the classification reported in Table 1 for the topics in the Bebras contest (Dagiene & Futschek, 2008).

After that meeting the members of the Bebras Organizing Committee agreed on the need of using all the types of the questions in Table 1 in every competition, they also confirmed an elective method for mandatory tasks and proposed a format (reported in Table 2) for the structure of the questions to be submitted to the committee for approval and inclusion in the competition.

Furthermore it has been emphasized that each Bebras task has to involve concepts of informatics and/or information management (Futschek & Dagiene, 2009). The Bebras organizing committee is persuaded in fact that pupils and students can learn advanced informatics concepts by solving Bebras problems when a good and age adequate

Table 1. Classification of Bebras contest questions

INF	Information comprehension	Representation of data (symbolic, numeric, visual), coding, encryption
ALG	Algorithmic thinking	Everything including programming aspects
USE	Using computer systems	Search engines, email, spread sheets, etc. general principles, but no specific systems
STRUC	Structures, patterns and arrangements	Combinatories, discrete structures (graphs, etc)
PUZ	Puzzles	Puzzles and games (e.g., mastermind, minesweeper, etc.)
SOC	ICT and Society	Social, ethical, cultural, international, legal issues

Table 2. Format for the proposal of problems for Bebras contest

TASK ID.	Made by nation code and progressive number (e.g., LT_19)
TITLE	Short title that characterizes the task most properly, max. 3 words.
QUESTION	Cover-story with definitions, metaphors, mini-world description, pictures, graphics etc. followed by the question to be answered
ANSWERS	Four alternative answers (one among them must be correct)
EXPLANATION	Explanation for the right answer and the wrong ones
INFORMATICS	The principles and concepts of informatics that are involved in the problem
REMARKS	Cultural remarks for translations
CATEGORY	One among the categories in Table 1
AGE GROUP / DIFFICULTY	One among the students' families (Benjamin, juniors, seniors) and difficulty: low, medium, high
AUTHOR/S	Name of the people who developed the question
FILES	Name of the task file and additional files
COPYRIGHT	Suggested the Creative Common 3.0 BY-NC-SA Licence

formulation of the task is adopted (Dagiene & Futschek, 2008).

At last it must be remarked that the questionnaire could be submitted to the students in two different ways: by using an online testing system or a pdf-based system where the students can download, compile and send back the tasks to the national committee.

DIGITAL LITERACY AND DIGITAL COMPETENCES

In addition to what has been reported until now on the instruments today available for improving computing/communication skills, and more generally digital skills in young generations, the outcomes of many studies on the difficulties people manifest in the acquisition of those skills must be considered.

The digital divide is probably the most important reason for digital illiteracy because it features today not only the presence or not of computing/communication instruments (like in the difference between developed and underdeveloped countries), but reports of at least two more complex problems affecting people's IT/ICT skills (Bindé *et al.* 2005; Guidolin, 2005):

a. The gap for pre-existing personal differences between people who are able in the use of technologies and people who are not,
b. The gap in the content management between people who master it (i.e., subjects who are able in the use of IT/ICT to manage information, knowledge, know how etc.) and people who don't.

The pedagogical emergency of digital divide, in all its aspects, is dramatically present all over the world and induced many private and public institutions, like Associations of Libraries, OECD and UNESCO, to act in two steps: first, to propose different hypotheses and strategies for the description of information literacy, computing literacy, digital literacy and media education, second, to suggest possible educational solutions for the improvement of those literacy.

The European Commission in 2005 issued the Recommendation on key competences for lifelong learning and stated the features of digital competence: the fourth among them (Commission of the European Parliament, 2005). The definition of this competence, which can be considered the most comprehensive until now adopted among those taken to date, like informatics literacy, information literacy, media literacy etc. is reported below:

This competence is based on the confident and critical use of Information Society Technology (IST) for work, leisure and communication and is underpinned by basic skills in ICT: that is the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet.

The presence of digital competences is intertwined with:

a. The understanding and knowledge of the nature, role and opportunities of IST in everyday contexts: in personal and social life as well as at work. It includes main computer applications, a sound use of the Internet and the communication via electronic media for leisure, information sharing and collaborative networking, learning and research,

b. The understanding of the support that creativity and innovation can receive from IST, the development of sound understanding skills helping state if information is valid, reliable and affordable enough and the knowledge of the ethical principles for the interactive use of IST.

The analysis of the connections between digital literacy (Tornero, 2004) and the development of digital competences for lifelong learning induced a group of Italian researchers and scholars in the Universities of Florence, Turin, Salerno and Cassino, to search for the features of a framework for the assessment of digital competence.

People in the research group agreed on the following features for digital competence:

•   It is multidimensional, because it implies the integration of cognitive, relational and social abilities and skills,

•   It is complex, because it cannot be completely measured by single tests and very difficultly can be

verified in a short run, because it requires more time and different contexts before becoming evident,

- It is interconnected, because it is not independent from other key competences like reading, numeracy, problem solving, inferential skills etc.
- It is sensitive to the socio-cultural context, because its meaning can change over time, according to context and to different educational settings.

FRAMEWORKS FOR DIGITAL ASSESSMENT

The mentioned features looked general and wider enough to be the basis for the sound development of a framework for digital competence assessment (Calvani *et al.*, 2008). Three levels of analysis have been proposed within that context: search for information, problem solving, and collaborative knowledge building. The last item was intertwined with students' skills which govern their movement in the cyberspace, in order to protect themselves from possible dangers and responsibly interact with others.

The hypothesized model for the framework for digital competence assessment is based on the co-existence of three different dimensions intersecting one another (Figure 1):

- **Technological:** That is, being able to explore and face new problems and new technological contexts in a flexible way;

Figure 1. Digital competence assessment framework
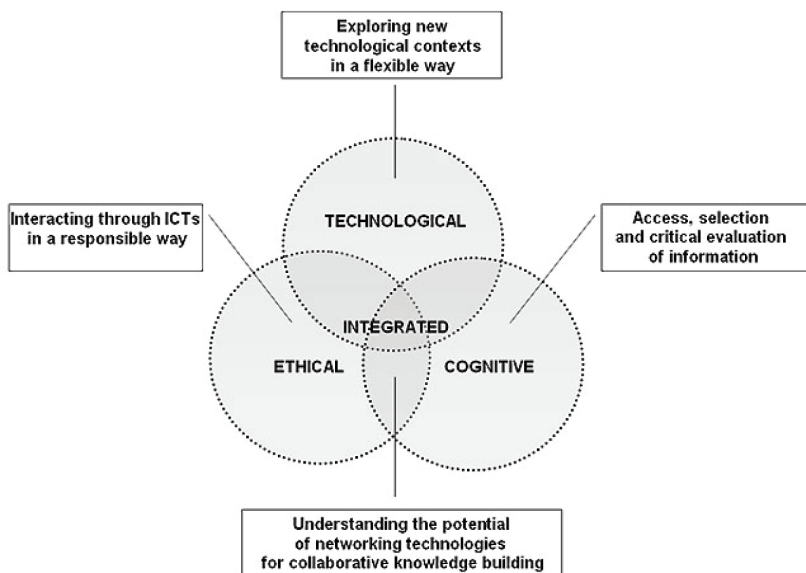
- **Cognitive:** Which means reading, selecting, interpreting and evaluating data and information, while considering their pertinence and reliability;
- **Ethical:** Which is expressed by the interaction with other individuals in a constructive way and with sense of responsibility (by using the available technologies).

The integration of the three mentioned dimensions is also possible and is based on the understanding of the potential offered by technologies, which let individuals share information and collaboratively build new knowledge.

By starting from the proposed framework, a test system with different kinds of analysis instruments has been hypothesised. First of all, the questionnaire called instant Digital Competence Assessment (iDCA), has been developed; its "instantaneous" feature is the consequence of its ease of use and application and its immediateness. Within it the following aspects are investigated (the Roman numbers stay for each of the three dimensions):

- recognizing environments and interfaces,
  - recognizing possible solutions for technological troubles,
    - selecting the most suitable technical solutions to problems,
    - dealing with logical operators and operations,

- charting out processes,
- recognizing the difference between real and virtual phenomena,
- dealing with texts (summarizing, representing, analyzing),
- organizing data,
- selecting and interpreting texts,
- selecting and evaluating relevant information,
  - evaluating reliability of information,
  - safeguarding oneself,
    - respecting others on the net,
  - understanding social and technological inequalities.

Once ready, the questionnaire has been submitted on article to students of different school levels and their answers have been analyzed. This first experience led researchers to adjust the structure of the questionnaire: it clearly emerged, in fact, that some questions had to be removed because they didn't produce any useful information; i.e., almost all the students selected the right answers or, on the contrary, the questions were too much difficult (i.e., in this last case more than 95% of the students selected the wrong answer or didn't answer at all).

After the suggested changes the Moodle platform was used to implement the questions and an invitation was sent to the schools in the neighbourhood of

the Universities in the project, to let teachers and students take part in the collection of the answers to the questionnaire.

Until now only a little number of school have been involved in the study and the researchers in the university of Florence decided to extend the invitation to participate to the schools on the whole nation.

The data collected with the article version of the questionnaire and the discussions of the results that the members of the research group had with teachers and colleagues working on similar problems, in national and international workshops and conferences, evidenced different needs and problems.

First of all, the questionnaire couldn't be the same while time passing due to the learning effect it had on teachers (i.e., classes of the same teacher answering the questionnaire at different times had better results if they participated in the experiment later than the others). Furthermore some criticisms concerning the model of the framework reported in Figure 1 explicitly emerged:

1. The ethical dimension looked much more normative than descriptive (i.e., most part of the aspects under analysis could only be present or absent in students), and it was very difficult, if not impossible, to measure and assess the competences it dealt with; a thorough analysis of this dimension showed also that it was inappropriate to describe any ethical student aspect, it aimed in fact at describing people compliance with rules for the use of technology and tools more than individual behavioural principles.

2. Both technological and cognitive dimensions produced questions in the cognitive domain and it looked suitable to join the two cognitive aspects in a unique dimension; otherwise stated, knowing how to use an instrument or a tool, recognizing an interface, developing an algorithm were considered knowledge and skills which could be immersed in real life situations and problems and could be investigated in a wider cognitive dimension.

3. The absence of the affective and social-relational dimensions negatively influenced the efficacy of the whole model, due to the effects the IT/ICT have on these spheres of individuals' life; as suggested from Ong (2002) and Olson (1991), for example, digital technologies led mankind to new forms of orality and social interaction. A possible remark supporting this criticism came from the observation that despite the lack of a social-relational taxonomy many questions concerning this issue were already present in the questionnaire (i.e., they mostly appeared in the ethical and cognitive dimensions of the framework).

The mentioned criticisms led to rethink the dimensions better featuring the interaction each individual has with

IT/ICT and, what is more important, to bring the individual at the core attention of the analysis for the presence of digital competences and their assessment. Three dimensions, as emerged from the discussions, looked essential:

- the cognitive,
- the affective,
- the social-relational.

For the first two among them the psycho-pedagogical literature and the corresponding educational taxonomies suggested suitable instruments of analysis, the last one needed a taxonomy to be made from the scratch. By hypothesizing the existence or the definition of a taxonomy for this last dimension a new framework was possible.

The cognitive dimension in the new framework unifies the cognitive and technological dimensions of the former framework. Main elements governing the assessment for this dimension come from Bloom categories: knowledge, comprehension, application, analysis, synthesis, evaluation (Bloom *et al*., 1956). A finer breakdown of the elements to be intertwined with digital competences in this dimension depends on the following elements: the verbal-linguistic and the logical-mathematical competences (deduced from the corresponding Gardner intelligences) and the skills derived from the construction and evolution of the concepts of space, time and causality (Piaget 1964, 1967). This last issue is the consequence of different needs:

a. The compliance of the questions to be created in this dimension with the problems usually adopted from the Bebras Organizing Committee, due to the identification of their aims,

b. The need of recovering the categories of space, time and causality that the use of the web, and more generally new technologies, modified; everyone can experiment in fact the contraction of spaces, the dilatation of times, and the loss of any causality when interacting with virtual worlds, using social networks and collecting results from search engines.

The use of the Krathwohl taxonomy (Krathwohl *et al.*, 1973) for the affective domain aims at extending the application of its categories to the interaction of the individual's affective sphere with digital technologies. The affective taxonomy, as derived from Krathwohl, is in fact based on the following categories: receiving phenomena, responding to phenomena, evaluating, organizing and internalizing phenomena.

The lack of a taxonomy for the social-relational taxonomy does not affect the new model which can be already used to assess the digital competences in the other dimensions. Once ready the last taxonomy will be added to the others and will better profile individuals' digital competences.

These considerations are well synthesized in the framework reported in Figure 2 (Cartelli, in press). In the figure, cognitive competences are split

into three areas: technological, verbal-linguistic and logical-mathematical, all under the umbrella of space, time and causality categories. In the same figure the affective and the social-relational dimensions are reported; the last one is also proposed under the influence of the intrapersonal and interpersonal intelligences (Gardner, 1993).

As in the previous model (Figure 1), the area in the intersection of all the dimensions can be thought as depending on the understanding and use of the potential of networking technologies for collaborative knowledge building. More generally the common area can be considered responsible for the ability of being able in the creation and development of communities of learning and practices.

CONCLUSION AND FUTURE WORK

The state of work in progress for the framework reported in Figure 2 does not lead to final conclusions for the structure of the instruments to be used for digital competence assessment. First of all, there is the need of collecting the ideas today available on the influence that digital equipments have on social-relational features of mankind and a taxonomy for the assessment of the corresponding competences must be defined. Once this target is hit, the correctness of the whole framework has to be verified and deeper analyses for the evaluation of the instruments to be used for digital competence assessment would be needed.

After these assumptions one could ask if it is still possible to use any in-

Figure 2. The synthesized digital competence assessment framework
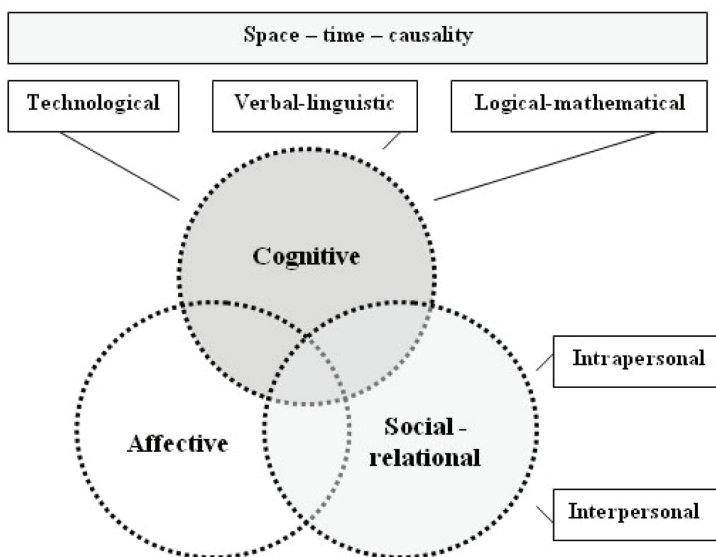
struments for the assessment of digital competences. Some answers to the above question come from the following statements:

a. The aims of the "Bebras contest" can be considered very close to the ones of the framework for digital competence assessment and the questionnaire, with the questions structured as described in Table 2, can be the instrument to be used for digital competence assessment,
b. The comparison of the families of questions in Table 1 with the dimensions of the model in Figure 2 suggest that:
    ◦ many questions in the iDCA (instant digital competence assessment) questionnaire can be recycled and included in the new questionnaire,
    ◦ all the questions in the "Bebras" contest can be considered a subset of all the possible questions in the final questionnaire,
c. The new synthesized framework is completely centred on the individual in his/her interaction with digital technologies (i.e., the individual is the subject of investigation), and some dimensions within it already have taxonomies which can help in the investigation of students' competences; as a consequence, at least the digital competences in the cognitive and affective dimensions can be analyzed.

In addition to what has been reported until now it has to be noted that further elements suggest the choice of a questionnaire structured like the ones in the "Bebras" contest:

a. A rigid questionnaire, made of fixed questions which don't change over time, is not compliant with people evolution and different students' generations; today students are in fact considered to belong to the net generation and to be digital natives, their knowledge and communication strategies, are showed to change quickly every school year, and the questionnaire must consider these changes as much as possible,
b. The questionnaire must change every year to avoid the training-effect on the teachers, which has already been experimented with the instant digital competence assessment questionnaire; it has been shown in fact that students of the same teacher in subsequent classes perform better than former ones, because they have been trained to face those questions.

At last, when the model will be verified and a final structure for the questionnaire decided, could we state that the answers from the students will suggest to teachers how develop suitable instruments and strategies for the improvement of digital competences?

The results that one of the authors had when submitted the instant digital competence assessment questionnaire

to the students in the schools in the neighbourhood of his university suggest a negative answer for the above question (Cartelli, 2008). In the meeting he held at the end of that experience, in fact, when teachers were invited to discuss and comment students' answers, they asked for support to improve their teaching strategies.

Until now no final strategy has been developed to hit the target of passing from teaching technologies to teaching with technologies in teachers in service training. The best results come from the involvement of teachers in the creation of learning objects for everyday teaching; those teachers who reorganize their teaching by using digital equipments and IT/ICT strategies perform better than the others in motivating the students and creating suitable learning environments. It is probably too early to say how much these results will influence the use of the questionnaire for digital competence assessment but it could be expected that the analysis of students answers will guide the process of planning and development of suitable learning objects to be used at school.

ACKNOWLEDGMENT

discussed digital literacy, digital competence assessment and the corresponding frameworks (section three and four in the article).

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