Toward Computer-Based Learning Environments that Promote Primary Students' Creative Thinking

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Abstract— **This paper presents (a) a theoretical investigation of the evolution of computer-based learning environments (CBLEs), (b) the correlations of CBLEs generations with learning theories and principles and (c) empirical data gathered from a survey of 542 Greek students from the 4th, 5th, and 6th grades. The data analysis reveals that the educational utilization of constructivist CBLEs, which are based on *Virtual Reality*, has the potential to bridge the gap between computer usage inside and outside school, promote students' creative thinking and learning, and enhance the accessibility and availability of learning resources. Preliminary criteria for the evaluation and development of such CBLEs are also recommended.**

***Index Terms*—Computer-based learning environments, evaluation criteria, creative thinking, learning principles.**

1. INTRODUCTION

Greek children of today are intensive users of various electronic devices, such as personal computers, cell phones, and game consoles [e.g. 1], living in a sociocultural environment that is shaped by Information and Communication Technologies (ICT). The extensive use of ICT by students, inside and outside school, has multiple dimensions, such as cognitive, learning, personal, social, and cultural. ICT in general and computers in particular, constitute a challenge for contemporary primary education that strives to utilize computer-based learning environments (CBLEs) in instruction and learning and keep pace with their rapid development. The authors of this paper define as CBLE any computer application (e.g. software, hypermedia, network, or database) that is used in a formal or informal educational setting (such as classroom, laboratory, or home) for supporting and enhancing learning.

In this paper, we investigate the potential role of CBLEs in enhancing the creative thinking of students, both inside and outside school. We consider this investigation valuable for teachers, parents, educational authorities, and policymakers because (a) students spend a large amount of time using computers inside and/or outside school, and (b) CBLEs offer unprecedented opportunities regarding students' creative thinking and performance. Based on a theoretical investigation and on empirical data we conclude that students benefit from meaningful and playful interactions with CBLEs. We also propose preliminary criteria for the evaluation and development of CBLEs that can utilized for the fostering of students' creative thinking.

1.1 Creative thinking and CBLEs

Recently, creative thinking has come to be viewed as an innate potential in all people that can be nurtured through education [e.g. 2]. It is also regarded as a crucial factor for responding to problems throughout all school subjects [e.g. 3] and across the challenges of everyday life [e.g. 4]. Consequently, the fostering of students' creative thinking has become a key target – albeit a challenging one – for contemporary primary education [e.g. 5].

Human creativity is a multifaceted phenomenon with cognitive, personal, social, cultural, economic, political, philosophical, and technological dimensions and is therefore difficult to define. In this paper, we adopt the definition of creativity within the framework of primary education proposed by Kampylis *et al.* [6]: "*creativity is the activity (both mental and physical) that occurs in a specific time-space, social and cultural framework and leads to some tangible or intangible outcome(s) that is/are original, useful, ethical and desirable, at least to the creator(s)*" (p. 18). This definition follows the *creative cognition approach* [7], which advocates that human creativity utilizes ordinary cognitive processes even in its most remarkable*1)* expressions. Therefore, everyone is capable of creative thinking and action [2], and creativity can be enhanced through education and schooling [e.g. 3].

Today, ICT has introduced new ways of creative expression, providing innovative tools, media, and environments that can contribute to the creative process and enhance the accessibility and availability of learning resources [8]. The utilization of CBLEs by primary-school students, inside and outside school, transforms the way they learn, leads to a multiplication of settings in which learning can occur, and provides new tools for learning [e.g. 1, 9]. By using CBLEs, students have the opportunity not only to be collectors and consumers of information, but also creators and collaborators [10]. They have the means to externalize, share, develop, and refine their thoughts, ideas, and inspirations in ways that could not be accomplished with traditional tools [e.g. 9].

However, it is not the access to CBLEs that can enhance students' creative thinking but the potential of CBLEs for supporting imagination, production, originality, and value [11]. Despite the growing interest and literature [e.g. 9] the creative utilization of CBLEs within the framework of primary education has not yet been fully recognized. CBLEs facilitate students' creative thinking when students are offered problem-solving and decision-making activities, and the environments help to transfer knowledge in higher-order skills. In addition, a CBLE effectively contributes to the educational process when it is integrated with hands-on activities and other resources in a playful, non-deterministic way [9, 12].

Primary education usually utilizes ICT in order to improve teaching as opposed to transforming it [13]. In other words, ICT is typically used to add to existing classroom practices rather than to replace them. However, the provision of ICT laboratories within schools does not automatically result in good teaching and learning practices [14]. Buckingham [8] argued that the everyday uses of ICT by children are mundane and not creative. What is creative is the way children learn to use ICT, mainly through learning by doing [e.g. 15]. Facer [15] pointed out that students' creativity and expertise regarding ICT tend to be inappropriately expressed as ingenious rule-breaking activities when there are no appropriate outlets within the school context. Therefore, primary education should not merely insert new tools into old practices; what is really needed is not a new educational technology but a *new educational culture* [16] that will utilize the new technology within a student-centered framework, targeting the fostering of all students' creative thinking.

2. THEORETICAL INVESTIGATION

In this section, we critically compare the four generations of CBLEs and their correlations with learning theories in an attempt to identify the characteristics of CBLEs that may promote students' creative thinking and learning.

2.1 Learning principles and human–computer interaction

Regardless of the way we view the learning process, four main factors can be identified [12]:

1. *The theoretical basis*, which consists of the main principles of a learning theory.
2. *The means of implementation*, which include teachers, textbooks, laboratories, and so on.
3. *The students*, who are the target-group of every educational system.
4. *External factors*, such as the sociocultural environment, educational policies, and funding.

The complex relations between the above factors, their interdependences, as well as the many variables that can influence them, render learning a complex and exceptionally delicate process. However, any learning process is based on the following learning principles:

1. *Learning is an individual phenomenon:* Each individual learns in his/her own way and at his/her own pace, interpreting the surrounding world in a different way; therefore, there is no single, "correct" representation of knowledge. This view stems from Piaget's work [17].
2. *Learning is a social phenomenon:* An individual learns because learning is essential for his/her existence. However, an individual learns not in a vacuum but within a social context, and therefore s/he is subject to unavoidable external influences. This principle originates from Vygotsky's work [18].
3. *The principle of uncertainty:* The four learning factors described above are subject to an almost infinite number of variables, both endogenous and exogenous. Hence, it is quite safe to proclaim that all learning theories are imperfect and incapable of fully describing the learning process [e.g. 19].

Owing to the principle of uncertainty, the following points hold true:

1. Learning is a dynamic process that occurs randomly and unpredictably at any place and at any time.

2. Learning objectives can be altered, partially or totally, in order to correspond with the progress of knowledge acquisition.
3. Learning outcomes are not predictable and certainly not predetermined.

All teaching methodologies must take advantage of every situation and transmute them into learning opportunities. They also have to be flexible enough to adapt to the needs of a person or a group of persons. Students become more capable of acquiring, maintaining, and generalizing new knowledge when they participate actively in the construction of this knowledge, in a *do-and-learn* process [20]. Therefore, the experience is the "vehicle" for the construction of knowledge.

As Winn [20] pointed out, we get to know the world in two ways, from *first person* and *third person* experiences. The former are derived from everyday contact with the surrounding world. Thus, they are direct, personal, and subjective experiences, in a way "silent" because we do not realize we have learnt something, and they do not require the use of any symbols. For example, what we feel and think when we watch a movie constitute first-person experiences. Third-person experiences, on the other hand, are derived from someone else's descriptions. Hence, they are indirect, explicit, and we usually realize we have learnt something, because someone else has taught us. For instance, we have third-person experiences when someone else describes to us the plot of a movie that we have not seen.

A key element that emerges from the aforementioned movie example is that first-person experiences are more "complete" than third-person experiences. Too much meaning, too much useful data is lost when a third party attempts to communicate complex ideas, concepts, or situations to us. It is much better to "see something with your own eyes" than to have an incomplete description of it. First-person experiences provide the learner with the opportunity to apprehend instinctively an idea/a unit of knowledge without the use of symbolic representations.

Computers offer third-person experiences to the user mainly because the information contained within them reflects the ideas/points of view/opinions of someone else (e.g. the developer's) and is only accessible through the interface, indirectly. In essence, the interface is the means of communication between the computer and the user through the operating system, input and output devices, programs, and so on. All such devices and programs use sets of symbols that differ from ordinary ones. For example, *double click* and *drag-and-drop* are symbols used by the mouse, and each has specific uses. As a result, these symbols stand between the user and the computer, making the process of knowledge acquisition more complicated.

The ideal would be to remove the second layer of symbols imposed by programs and devices in order for the bilateral *human–computer interaction* to be conducted in a more "natural" way, the way we interact with the real environment. By achieving this, the interface can become almost invisible, and the user may gain experiences closer to those of the real world.

2.2 CBLEs comparison and evaluation

The first generation of CBLEs (see Table 1) adopted behavioristic approaches and focused on content. They analyzed the knowledge and skills that students should acquire in constitutive elements, where a total comprehension of these led to the expected behavior. A characteristic example of this view was *Computer Assisted Instruction* (CAI), which assumed the form of "drill and practice" with the learner having minimal control over what s/he learnt. Everything was predetermined by the designer, even though in some cases the user was given the opportunity to omit specific elements [21].

In the second generation, there was a shift from emphasis on the content to emphasis on the means. The basic idea was that the means by which the user processes information could be more important than the information itself. Cognitive theories offered essential theoretical support to the designers of educational applications. Typical examples of this generation are applications programmed in such a way that they appear to "think" about and reply "intelligently" to a student's data entry. However, the objective remained the same: conveying knowledge to the learner in the best possible way [22]. In both cases, the designer breaks down the cognitive material into small units. The goal in the behavioristic approach was to achieve the desired behavior, whereas in the cognitive approach it was to achieve transition from simple concepts to complex ones.

Constructivism provided a robust theoretical background on how the third generation of CBLEs could enhance not only knowledge acquisition and learning, but also creative thinking. It supported the view that predetermined and foreseeable cognitive results do not exist and, therefore, that teachers should encourage, not guide, the learner. Jonassen [23] listed the following characteristics of constructivist instructional planning, which correspond with those suggested by creativity researchers [e.g. 24] for the development of students' creative thinking:

1. Make available multiple representations of reality and present the natural complexity of the world in order to avoid simplifications.
2. Offer authentic tasks to students.

3. Provide instructive environments that support the study of real cases.
4. Construct knowledge in association with the frame and the content that is applied.
5. Encourage practices that support reasoning.
6. Support collaborative learning, not competition between students.

Multimedia and hypermedia are types of computer application that largely satisfy the above conditions, allowing a non-linear course in teaching and giving students the opportunity to choose their own path. Thus, they are extensively used for the materialization of constructivist perceptions. However, there is the fear that students may become disorientated, lost in the maze of choices and hyperlinks. To avoid this, many researchers [25] propose a combination of old and new instructive methods, and a progressive increase in student control over the instructive process.

Yet, there is a fourth generation of CBLEs, based on 3D graphics and 3D animation, which also materializes constructivist ideas. The term used for these applications is *Virtual Reality* [e.g. 12]. Winn [20] noted that in this type of CBLE the use of symbols is not essential. In all other generations of CBLEs, computers offered third-person experiences to the user for the following reasons:

1. The computer interferes between the individual and the information that it contains.
2. The information emanates from somebody else who has imported it to the computer.
3. Information is not immediately available but through the interface and devices such as screen, mouse, and keyboard that use systems of symbols.
4. These symbols require some thinking by the user to be utilized effectively.

Consequently, computers do not offer first-person experiences to the user.

Constructivism provides fruitful ideas on how this type of experience can be acquired by using computers. Two of these ideas [e.g. 20] form our main points of focus:

1. The interface must be absent; in a way, the computer should be invisible. This means that the user should employ methods that do not use symbols for his/her interaction with the computer instead of traditional ones such as keyboard.
2. The interaction between the user and the computer (or between users) should not be predetermined. Instead, all types of interaction should be possible.

Such constructivist CBLEs, which are based on virtual-reality applications, can satisfy all learning principles. This is because (a) they utilize multiple representations through specially designed equipment instead of symbols, (b) they allow social interactions, and (c) interactions are not predetermined. As a result, learning in a virtual-reality environment is a dynamic process determined by the user who defines the objectives and alters them at will.

Therefore, the CBLEs of the fourth generation are the most suitable for enhancing learning and creative thinking within primary-education settings because

1. they offer students learning environments that demand problem-solving and decision-making schemata;
2. they are compatible with the “average” student’s everyday life because s/he is already an intensive ICT user; and
3. computers can be seen as both a tool and a medium for students’ higher-order engagement in creative processes.

Table 1: Comparison of CBLEs generations

	1st generation	2nd generation	3rd generation	4th generation
Theoretical background	Behaviorism	Cognitive theories	Constructivism	Constructivism
Student's role	Passive	Active	Active	Active
Emphasis	Content	Interaction	Interaction	Interaction, Open design
First-person experiences	No	No	No	Yes
Third-person experiences	Yes	Yes	Yes	Yes
Use of symbols	Yes	Yes	Yes	Yes/No
Learning as an individual phenomenon	No	Yes	Yes	Yes
Learning as a social phenomenon	No	No	Yes	Yes
Principle of uncertainty	No	No	No	Yes
Indicative applications	Text, Educational games	Educational games	Multimedia, Hypermedia	Virtual reality

Virvou and Katsionis [26] stated that students benefit more from an educational virtual-reality game than from conventional educational software, learning a number of skills and strategies with the former. However, evaluation must be an essential and continuous element of the design and realization process of all CBLEs. They should be tested not only by developers and other experts but also by students and teachers in real situations, redesigned if necessary and then tested again [27].

Our ongoing research, based on theoretical investigations as well as on empirical data, aims to specify criteria for the evaluation and development of CBLEs that facilitate students' creative thinking. These criteria include:

1. An open design with non-predetermined, dynamic human–computer interactions.
2. The support of synchronous and asynchronous, non-predetermined interaction between users.
3. Joyful, motivational, and transformational learning experiences.
4. Real-world, meaningful, open-ended, and *1)* challenging tasks and problems.
5. Constructive assessments.
6. An emphasis on collaboration and teamwork.
7. More opportunities for feedback, reflection, and critical thinking.
8. The utilization of multimodal representations.
9. The absence of symbols and an almost invisible interface environment.

3. Empirical investigation

Our theoretical investigation indicates that the fourth generation of CBLEs may offer opportunities for authentic and creative learning experiences within the framework of primary education. Next, we present empirical data on where and how Greek primary-school students from urban areas use computers inside and outside school and how they learn to do so.

3.1 Method

In order to investigate where and how Greek primary-school students learn to use computers we developed a self-report, anonymous, pencil-and-paper questionnaire. The questionnaire comprises over 22 items (Likert-type scales as well as open-ended and multiple-choice questions).

The initial questionnaire was piloted in a local Athens primary school (N=52) in December 2009. The modified questionnaire was printed out and distributed in January 2010 to 558 students of 4th, 5th, and 6th grades of eight Greek state primary schools in the Athens area (Table 2). Sixteen out of the 558 questionnaires (3.3%) were not completed adequately, so the valid questionnaires were 542 (N=542). The participants' ages ranged between 9 and 12 years (mean 10.9 years).

Table 2: Demographics of the participants

	Boys # (%)	Girls # (%)	Total # (%)
4th	96 (47.3)	107 (52.7)	203 (37.5)
5th	101 (56.7)	77 (43.3)	178 (32.8)
6th	90 (55.9)	71 (44.1)	161 (29.7)
Total # (%)	287 (53.0)	255 (47.0)	542 (100.0)

Students completed the final questionnaire voluntarily, in prearranged lesson time in the presence of their class teacher. A researcher was present at school in order to answer any queries arising and collect the questionnaires.

3.2 Findings

The data analysis (Table 3) was conducted through *SPSS Statistics 15.0* software revealing that (a) computers play a significant role in students' lives and (b) there is an increasing gap between how they use them inside and outside school. More analytically, the vast majority of the participants (91.8%) have access to a personal computer at home, almost one out of two has computer in his/her own room, and 65.3% feel confidence in using it. These findings are consistent with those of similar studies conducted previously in Greece [1, 12, 28]. The research data also reveals a rapid growth in the use of computers at home by students during 2009, taking into consideration that almost one out of three students (30.7%) had a computer at home in 2000 [29], one out of two in 2005 [1] and four out of five in 2008 [30].

However, our data also indicates that while four out of ten students (39.9%) use a computer at home almost everyday, at the same time one out of ten students (8.1%) does not have access at all to a computer. This *digital divide "…involves far more than mere physical access to technology*" [15, p. 236], and Greek primary schools should offer not only physical access to computers for these students but also real computer-based learning opportunities for all students.

Table 3: Main findings of the survey

	4th	5th	6th	Total
PC at school				
PC laboratory	37.5	32.8	29.7	100.0
In the classroom	2.2	2.4	2.6	7.2
PC at home				
None	4.1	2.6	1.5	8.1
One	20.1	22.0	18.1	60.1
Two or more	13.3	8.3	10.1	31.7
In my own room	16.2	15.5	16.4	48.2
I use the PC at school…				
Never	23.8	20.1	21.6	65.5
Rarely	10.9	9.4	7.2	27.5
2-3 times a month	2.2	1.7	0.7	4.6
2-3 time a week	0.6	1.5	0.2	2.2
Almost every day	0.0	0.2	0.0	0.2
I use a PC at home…				
Never	3.7	2.8	1.7	8.1
Rarely	5.2	5.2	2.6	12.9
2-3 times a month	3.5	4.4	4.1	12.0
2-3 time a week	10.0	9.0	8.1	27.1
Almost every day	15.1	11.4	13.3	39.9
I use the PC at school for…				
Homework	7.6	6.3	3.5	17.3
Gaming	9.2	10.5	4.1	23.8
Internet	2.6	0.9	1.5	5.0
Communicating	1.3	0.7	0.4	2.4
Other	1.5	0.9	2.6	5.0
I use the PC at home for…				
Homework	18.6	16.1	14.9	49.6
Gaming	28.6	25.1	24.9	78.6
Internet	14.8	15.1	16.8	46.7
Communication	11.4	10.9	13.7	36.0
Other	3.1	3.7	3.3	10.1
I use 3D applications…				
at school	1.1	1.8	0.6	3.5
at home	31.5	26.8	26.4	84.7
I know how to use a PC…				
Very well	15.1	11.1	11.1	37.3
Well	9.4	8.9	9.8	28.0
So and so	6.5	9.2	6.6	22.3
Little	4.2	2.6	2.0	8.9
Very little	1.1	0.7	0.0	1.8
Not at all!	1.1	0.4	0.2	1.7
I learnt to use the PC from…				
School	5.5	3.9	3.3	12.7
Tuition center	6.3	4.2	2.8	13.3
Parents	17.9	12.0	10.0	39.9
Peers	5.5	6.5	6.8	18.8
Alone	28.8	27.3	26.2	82.3
Other	7.4	8.1	6.3	21.8

Students use computers at home mainly for playing games (78.6%). These findings have been echoed by several similar studies in Greece [1, 12, 28, 29]. They are also in line with studies conducted worldwide. For instance, Sandford *et al.* [31] reported that 85% of British students play computer games outside the classroom. Moreover, the majority of British teachers and students support the idea of using games in formal curricular contexts because such use motivates students and improves their computer skills and general problem-solving abilities. The main barriers perceived by teachers in the use of computer games do not concern the curriculum or assessment but the technical issues that need to be overcome.

The vast majority of students who participated in our survey reported that they learned to use a computer outside school, mainly through exploratory learning by *trial and error* and *learning by doing* (82.3%). Parents (39.9%) and peers (18.8%) are the *important others* who make essential contributions to this learning process. These findings are in line with those reported by other researchers [1, 12, 28, 29, 32, 33], and reveal that most of the average student's computer expertise is gained from intensive use outside school.

The model that Greek primary education has adopted for the implementation of computers at school, namely through a separate ICT laboratory seems not functional. Thus, although all the schools that took part in this survey have operational ICT laboratories, the 65.5% of the students reported that they do not use them.

Last but not least, the vast majority of the participant students (84.7%) reported that they use applications that based on 3D graphics and 3D animations only in their home computers whereas only 3.5% have used them in their schools.

4. Discussion

We consider it useful to draw attention to the main limitations of our survey before discussing the findings. First, we measured the students' attitudes to using computers by means of a self-report questionnaire. So, the findings of the survey do not necessarily represent students' actual attitudes toward using computers. Second, the participants constitute a small, non-representative sample of Greek primary-school students. Finally, the responses to the questionnaire reflect students' attitudes toward using computers for a specific time period but not their fluctuation over a longer period

According to our empirical data, most of the Greek primary-school students feel confident with and use computers, but they learn about and use them mainly outside school. This distinction between computer usage inside and outside school has two dimensions, a quantitative and a qualitative one. On the one hand, it is quantitative because (a) students use the computers in their homes more than in their schools, and (b) the use of computers by students outside schools is growing faster than their use in schools [see also 13, 33]. On the other hand, it is qualitative because students have access to more powerful and new computers in their homes than in their schools [see also 12, 33].

Greek primary education strives to keep pace with the development of new technologies, but the accessibility and availability of digital learning resources remains limited [1, 28]. Moreover, there is a paradox in that, in many cases, primary education strives to teach students basic ICT skills despite many already being experienced users. As a result, students with expertise in using ICT are forced into the position of novice learner within the school environment, thus losing interest and motivation [15].

Our experience not only as researchers but also as teachers and parents who interact with children on an everyday basis and the analysis of our empirical data show that students spend much of their free time playing computer games. As a result, they conceptualize and use the computer as both a toy and a playable tool [34]. The problem is that in school settings students use computers for less entertaining and meaningful activities, such as word processing. What needs to be stressed, therefore, is that students use computers in school in a way that usually does not promote creative thinking, whereas at home the opposite is true.

Consequently, we support the argument that "*…school use of ICT is just the tip of the iceberg – we need to explore the other nine-tenths*" [13, p. 243] and that a gap exists between computers in school and outside school in terms of frequency of use, type of software and hardware, and style of interaction. However, today it is easier to create CBLEs that promote exploratory learning by offering authentic, open-ended, and meaningful first-person experiences. Constructivist CBLEs may help students to visualize abstract and complex concepts such as sound waves [9]. If a CBLE is to develop into an integral part of the learning experience, the main precondition is that it must become almost invisible and offer first-person experiences. Moreover, the emphasis must be shifted from "*...what computers could do*" to "*what users can do*" [35, p. 2].

5. Conclusions and further research

According to our theoretical and empirical investigation, students learn how to use computers mainly outside school and through exploratory learning by *trial and error* and *learning by doing*. This type of effective learning contrasts strongly with the dominant pedagogical approaches in Greek primary schools that continue to separate learning and doing [e.g. 12]. These different approaches produce tensions when teachers employ CBLEs within traditional pedagogical frameworks, and when students realize that their effective-learning strategies are discounted within the classroom. Furthermore, as students become intensive ICT users in their homes, developing skills and predispositions, the gap between learning at home and learning at school becomes wider. Pedagogy that reflects a convergence between learning inside and outside school should take into account that students consider computers as *playable machines* [34], and that they learn more effectively by means of exploratory learning.

The increasing effect of ICT appliances in general and computers in particular on the everyday lives of students provokes many questions that necessitate further research: What are the implications of students' domestic ICT use for primary education? How could primary education bridge the gap between ICT inside and outside school? How could primary education bridge the gap between students who use ICT at home and those who do not? What type of training do educators need in order to utilize the opportunities CBLEs offer for enhancing students' creative thinking? How can learning in the classroom benefit from the successful use of computers outside school? What are the short- and long-term effects of CBLE use inside and outside school on students' learning and creative thinking? What type of CBLE do we need in order to facilitate students' creative thinking and learning? What should be the evaluation criteria for such CBLEs?

As Bransford *et al.* [36] have pointed out, what has not yet been fully understood is that

> "…computer-based technologies can be powerful pedagogical tools – not just rich sources of information, but also extensions of human capabilities and contexts for social interactions supporting learning. The process of using technology to improve learning is never solely a technical matter, concerned only with properties of educational hardware and software. Like a textbook or any other cultural object, technology resources for education – whether a software science simulation or an interactive reading exercise – function in a social environment, mediated by learning conversations with peers and teachers." (p. 218)

However, contemporary educational systems are still dominated by individualized forms of assessments promoting individualized models of learning [e.g. 15] and competition [e.g. 35]. As a result, the potential of using CBLEs for creative and collaborative models of learning, such as *distributed problem-based learning* [37], is often ignored by primary education.

In conclusion, constructivist CBLEs, which are based on virtual-reality applications, may enhance the accessibility and availability of learning resources and offer primary-school students meaningful, motivating activities that trigger their creative thinking and improve the learning process.

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