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# ATMF: A student-centered framework for the effective implementation of alternative teaching methods for CSEd

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**Abstract.** The dynamic development of Informatics introduces new educational and pedagogical challenges, including the instructional design of teaching and learning. How can we teach our students better in such a growing and demanding field? Moreover, how can we motivate them and together have better learning results? This paper aims to give answers to these questions, through a student-centered framework for effectively encompassing alternative teaching methods within CS. The proposed framework (ATMF) summarizes the benefits of alternative teaching methods in contrast with known issues of traditional teaching. In addition, ATMF is built upon empirical evidence and concludes that alternative practices, if used under the right conditions, can provide increased motivation for learning and better learning outcomes.

**Keywords:** Computer Science Education, Teaching Framework, Alternative Teaching Methods.

## 1 Introduction

Informatics -also termed as “Computer Science” (CS)- is on the brink of an enormous possible growth and therefore it draws great interest from governments, businesses and other organizations as a top educational priority. Moreover, the dynamic development of the field introduces new educational and pedagogical challenges, including the instructional design of teaching and learning. How can we teach our students better in such a growing and demanding field? Furthermore, how can we motivate them and together consume better learning results?

Alternative Teaching Methods (ATM) that support students’ active involvement in the learning process, according to the constructivism and constructionism principles, could be very helpful [1]. Alternative is considered everything that is relating to activities that depart from or challenge traditional norms<sup>1</sup>. Therefore, ATM refers to providing students with different approaches/strategies to learning the same information. There are several instructional methodologies used by educators and researchers in order to deal with the complexity and the needs of various cases. Nevertheless, using them could be adapted in more approaches with similar features. As Morrison, Ross [2]

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<sup>1</sup> Cambridge Online Dictionary: <http://dictionary.cambridge.org/dictionary/english/alternative>, last accessed June 2019

state, instructors at any level of education should implement various pedagogical approaches and teaching methods when the discipline and learning tasks vary.

However, most instructors have little practice or experience with teaching methods other than traditional lecturing [3]. Some have a particular teaching style that they use in every teaching context, regardless of the type or level of student learning they expect. Others, because of the CS discipline, may already use various technology applications, but their decisions may not be based on student-centered pedagogy [4, 5]. Finally, a number of instructors are concerned that students will respond negatively to teaching and learning activities that are new to them [6]. Thus, any of these factors can hinder the reframing of teaching to a student-centered perspective. It becomes apparent that there is a need for a clear and easy-to-adopt, student-centered framework encompassing alternative teaching concepts.

One may argue that several models exist, standards, curriculum guidelines or frameworks that can be used for teaching and learning purposes. However, most of them refer to teaching in a general scope [7] or teaching in a specific discipline different from CS, like frameworks from math, science, and technology education. Therefore, the existing frameworks neither consider the identity and particularities of CS Education (CSE), nor prescribe suitable alternative teaching strategies. For example, within the CS field, the “K–12 Computer Science Framework”, describes the foundational literacy in CS, aiming to show that CS is essential for all students [8]. This framework includes standards, curriculum, course pathways and even professional development suggestions for all K–12 grade levels, but it does not include any specific teaching guidelines. Other national frameworks, describe CS concepts and practices that students should know, but do not focus on alternative teaching methods. Finally, other well established frameworks in higher education, like the Advanced Placement CS Principles curriculum framework and the ACM’s curriculum guidelines for undergraduate CS programs [9], provide standards for students and curricula, but not for teachers who want to teach students. Additionally, although a teaching framework could be based on existing research and well-established practices, it should also be evolving, taking into account new empirical studies. The lack of empirical research on best practices in CSE has led researchers to repetitively ask similar basic questions without clear progress toward resolving them, although current practical research shows promise [10].

Given the above-mentioned research motivations, it is clear that there is potential for learning achievement to be improved in CSE through the effective design and use of new methods, strategies and approaches. Thus, the aim of this study is the development of a student-centered framework for teaching that can provide shared understandings, which can help improve the quality of instructional design, course and lesson planning, learning and assessment.

The next section maps a territory of topics encountered in CSE. The third section presents the proposed framework and the fourth section presents briefly the empirical studies that were conducted during its formulation. Finally, we summarize this article in the fifth section.

## **2 Background work**

### **2.1 The CS discipline**

CSE is learning about CS and focuses on teaching the fundamental concepts of the discipline, just as core Mathematics and Physics courses do. Nevertheless, confusion arises when trying to distinguish between the most common areas of computing education offered in schools like CS, IT and Educational Technology [11]. There are many different aspects of CSE. To the same reason, there is an ignorance about the core concepts and characteristics that students are taught through CSE. This reflects to the wider ignorance by the general public about the nature, methodologies, and contributions of the field in the modern world.

However, through CS learners can acquire many valuable skills and characteristics, beyond the narrow scope of programming. Coding is an indispensable tool for CS, enabling the creation of software, but CS is a broader field covering many different concepts that go well beyond coding. Through CS, one can develop logical reasoning and gain awareness of the resources required to implement, test, and deploy a solution, and how to deal with real-world constraints. All these skills are applicable in many contexts, from science and engineering to the humanities and business, and they have enabled deeper understanding in these and other areas.

### **2.2 Traditional Strategies Issues**

Probably the main argument posed against traditional classroom styles involves how little it truly engages students [12]. In addition, traditional, lecture-based structures serve particularly adroit conduits for rote learning and memorization. Another issue with traditional strategies involves teacher bias. Most subjects are not objective, and since the instructor stands as the highest authority in the room, the more strict, rote structure only presents some perspectives on the matters at hand [13]. The most effective educational settings are more active and allow students to consider content from multiple angles and form multiple opinions, rather than adopting what teachers transfer [12]. Moreover, not every teacher is good at public speaking. Poor communicators and speaking anxiety can seriously screw over different learners, even if they typically benefit from traditional lecture structures [14]. It is crucial that teachers understand where their public speaking limitations lie and alter their styles accordingly for maximum educational achievement [14].

Furthermore, traditional strategies may suit better some students than others and strengthen a limited number of skills. The highly dynamic field of CS demands that learners must be empowered with reflective lifelong learning skills in order to be successful. They need to develop skills such as CT, problem solving, teamwork, communication, critical thinking, and creativity. The traditional teacher-centric pedagogy is focused on the course content and only on transferring knowledge to the students whereas a learner-centric view is focused on assisting students to develop or build knowledge [15]. In CSE a move to a learner-centered design is recommended [16], because active elements of a 21<sup>st</sup> century education receive little attention. Therefore,

reliance on the traditional lecture as the main mode of student learning has been criticized and new alternative strategies are needed.

### 2.3 Alternative Teaching Methods

In addition to traditional teaching, educators and curriculum designers must consider learning activities and instructional techniques that aim to student motivation and learning. There are many parameters that need to be considered, like the students' age and experience on technology matters or the learning goals. There are also several methods used by educators and researchers in order to deal with the complexity and the needs of various cases. Table 1 gives a summary of the ATMs used in CSE by the time this article was written.

**Table 1.** Alternative Teaching Methods used in CSE.

1	Peer Learning	11	Non-Textual Programming
2	Problem-Based Learning	12	Contextualized Learning
3	Project-Based Learning	13	CS Unplugged
4	Studio-Based Learning	14	Subgoal Learning
5	Inquiry-Based Learning	15	Programming Puzzles
6	Process Oriented Guided Inquiry Learning	16	Extreme Programming
7	Team Learning	17	Program Visualization
8	Game-Based Learning	18	Competency-Based Learning
9	Educational Robotics	19	Social Networks Learning
10	Physical Computing	20	Emerging Technologies

## 3 The ATM Framework

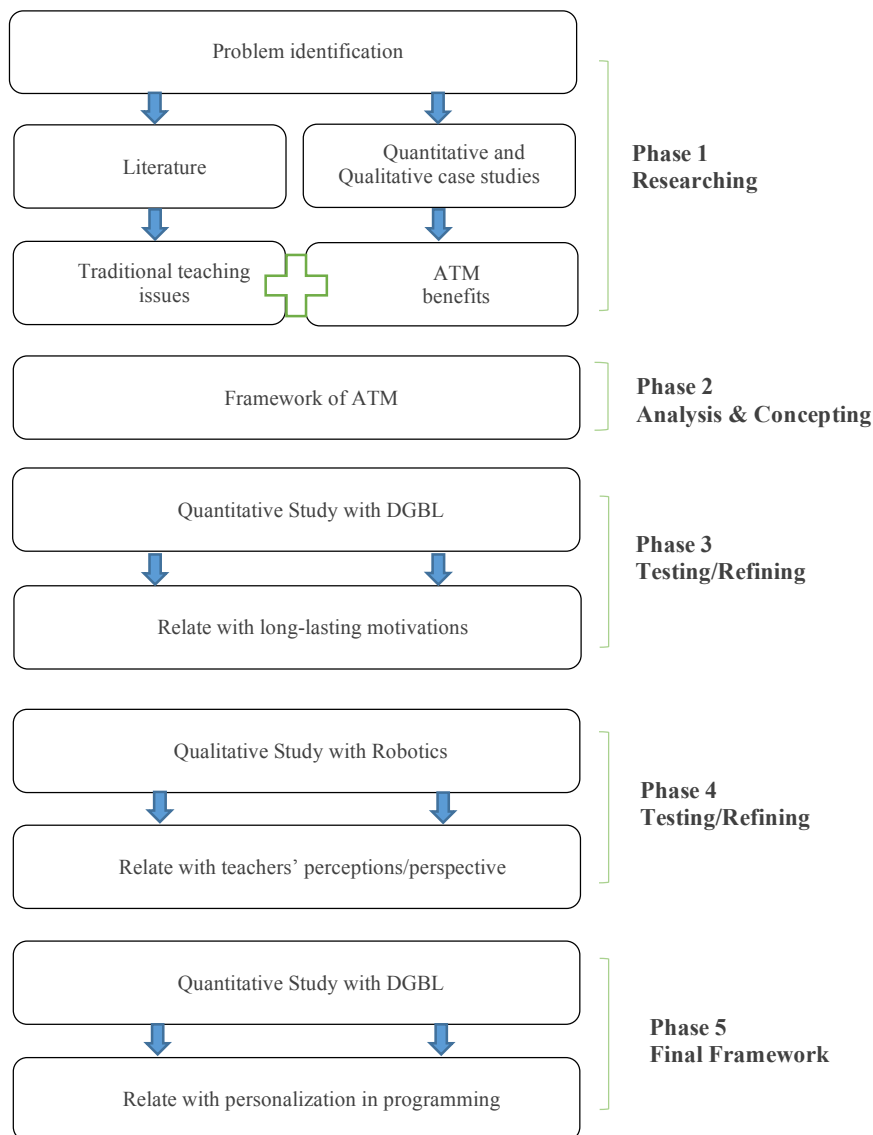
Learning different CS concepts more effectively, requires the development of a multi-level framework that could be applied in different contexts using different teaching approaches to a multitude of application domains. This article proposes a framework for the effective implementation of ATM in CS.

### 3.1 A new conceptual framework

This new framework is called the ATMF (Alternative Teaching Methods Framework). ATMF is a broad description of the context, characteristics, content and sequence of learning expected of all learners - but not at the level of detail of grade-by-grade standards or, at the course description and standards. Figure 1 illustrates the five phases of the methodology that was adapted in order to develop the ATMF. The current literature on ATM, has provided the theoretical framework for the studies reported in this paper. The proposed framework is intended as a guide to instructors (formal or informal settings) as well as for curriculum designers, assessment developers, researchers and professionals responsible for CSE. Thus, it describes the major concepts, and disciplinary core ideas that all instructors should be familiar with in order to enhance their teaching with alternative strategies, and providing an outline of how these practices, concepts,

and ideas should be developed across different settings. ATMF was based both on previous theoretical frameworks and models as well as empirical guidelines.

**Fig. 1.**The five-phased methodology adapted for developing the ATM framework.



*Phase 1:* We researched alternative teaching methods within CS, other frameworks and contacted two initial empirical studies with quantitative and qualitative data. Background expert work from well know educational models and frameworks was reused. The process on one hand revealed the teaching issues that the traditional teaching methods have and on the other hand highlighted the key advantages of ATM.

*Phase 2:* We analyzed the concepts used at the ATMF. In this phase the framework was initially shaped through literature review and the initial empirical research.

*Phase 3:* We tested and refined the ATMF. In this phase the framework was examined and enhanced with additional elements through another empirical research study with Digital Game-Based Learning (DGBL).

*Phase 4:* We tested and refined the ATMF. In this phase the framework was tested again and enhanced with additional elements, though another empirical research study.

*Phase 5:* We tested and shaped the final ATMF. In this phase the framework was tested once more, enhanced with additional elements and finalized.

### 3.2 Analysis - Concepting

The ATMF comprises the need to consider context, content, pedagogy, instructor and the learner as part of the design process, so-called dimensions. Dimensions contain components, where each component defines a distinct aspect of a dimension and components are consisted of elements that describe specific features.

**Table 2.** Components and Elements of Dimension 1.

<b>Dimension 1: Context</b>	
<b>Component 1a</b>	<b>Education Level</b>
	Element 1      Formal Education / Type of School / Level
	Element 2      Informal Education
	Element 3      Non-formal Education
<b>Component 1b</b>	<b>Environment (physical)</b>
	Element 1      Infrastructure (availability)
	Element 2      Supporting Resources
<b>Component 1c</b>	<b>Educational System</b>
	Element 1      Policies
	Element 2      Compulsory Curriculum
	Element 3      CS standards
	Element 4      General public attitudes
	Element 5      Time restrictions

In particular, in advance of planning a lesson with the use of ATMF, it is suggested that a comprehensive learning analysis be produced that sufficiently covers the following standpoints:

**Dimension 1. Context:** The components in this dimension describe the surrounding environment around the learning process (Table 2). This dimension deals with the need to consider the educational level and the place where learning is taking place, the resources available (e.g. access to laptops/computers, mobiles, technical support), and the disciplinary context (e.g. in school, in ICT lab, in a university, at home, in the workplace). The components establish the environment that supports the learning and are not directly associated with the learning of any particular content, instead, they set the stage for all learning processes. The specific elements of the learning environment are captured in three categories: Teaching Level, Classroom Level and Educational System.

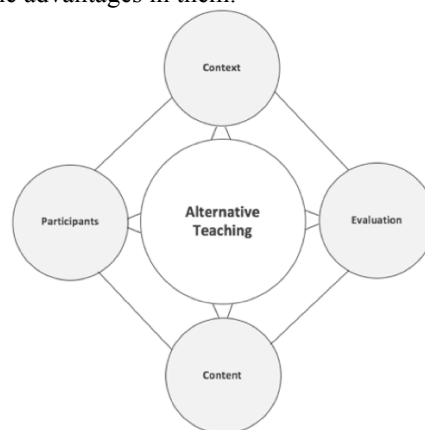


**Dimension 2. Participants:** This dimension describes the participants' characteristics in two main components, learners and instructors (Table 3). The environment including the relationship between instructor and learners and the cultural norms (characteristics) play a significant role in what can and does occur during the teaching and learning. Both learner and instructor characteristics are important for instructional designers as they allow them to design and create tailored instructions for a target group.

**Table 3.** Components and Elements of Dimension 2.

<b>Dimension 2: Participants' Characteristics</b>		
<b>Component2a</b>	<b>Learner-related</b>	
	Element 1	Age
	Element 2	Gender
	Element 3	Cultural background
	Element 4	Socioeconomic status
	Element 5	ICT use
	Element 6	ICT experience
	Element 7	Attitudes
	Element 8	Personality traits
<b>Component2b</b>	<b>Instructor-related</b>	
	Element 1	Age
	Element 2	Gender
	Element 3	Teaching experience
	Element 4	Academic characteristics
	Element 5	Skills - Abilities
	Element 6	Attitudes
	Element 7	Personality Traits

Component 2b also contains instructors' attitudes (element 6) about alternative ways of teaching. For instance, teachers that prefer traditional teaching believe that it gives better learning results and hesitate to include active-learning methods in their teaching, although they see some advantages in them.



**Fig. 2.** The ATM Framework for CSE.

Finally, personality traits (element 7) relate to such things as actions, attitudes and behaviors that determine different personality styles like cognitive style and intelligence

type. Being positive and upbeat can influence learners around an instructor, and so can negativity. The personalities of both instructor and learner interacting with one another and with the content create a unique environment. It is expected that by taking into account the participants' characteristics can be designed and developed more efficient, effective and motivating instructional materials.

**Dimension 3. Content:** The components of this dimension reflect process workflows from teaching and learning theories and from the ATMs. Those components describe how an instructor organizes the content that the students are to learn and how he/she designs instruction (Table 4). Component 3a comprises of five elements, related to what is the content to be taught. Elements 1 to 3, refer to lesson planning and effort to answer queries like: What is the subject to be taught? What are the objectives and goals that instructor aims to achieve? Does the lesson planning refer to short or long-term features? etc.

**Table 4.** Components and Elements of Dimension 3.

<b>Dimension 3: Content</b>		
Component3a	<b>Learning</b>	
	Element 1	Subject
	Element 2	Objectives
	Element 3	Short-term & Long-term Planning
	Element 4	Expectations for learning
	Element 5	Relations to other subjects / disciplines
Component3b	<b>Teaching</b>	
	Element 1	Lecture-based
	Element 2	ATMs

**Dimension 4. Evaluation:** This dimension addresses the outcomes of the teaching and learning processes, which deal with assessment and evaluation. The outcomes (direct or indirect) are examined in two main components as shown at Table 5.

**Table 5.** Components and Elements of Dimension 4.

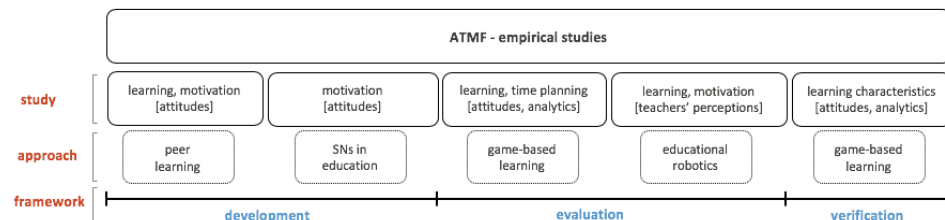
<b>Dimension 4: Evaluation</b>		
Component4a	<b>Learner-related</b>	
	Element 1	Knowledge / Performance
	Element 2	Motivation
	Element 3	Skills
	Element 4	Metacognition
	Element 5	Beliefs
Component4b	<b>Instructor-related</b>	
	Element 1	Assessment Criteria / Method
	Element 2	Monitoring of Learning (Learning Analytics)
	Element 3	Feedback to Learners
	Element 4	Long-term Evaluation
	Element 5	Teaching Evaluation

### 3.3 Shaping the ATMF

Fig. 2 (above) provides the visual description that was used to for the ATMF. This visual recognized the importance of multiple dimensions of: context (describing the setting, curriculum, policies and infrastructure), participants (describing the instructors and learners' characteristics), content (describing the subject matter, purposes and values, pedagogy and strategies) and evaluation (describing the outcomes for both learners and instructors). Those four dimensions are presented as being a complex and interconnected whole with ATM at the hub connecting all the dimensions. ATM is in the center of all the process in order to emphasize that instructors have to think about and reflect upon the multiple dimensions as they investigated each topic or assignment of implementing ATM. The overall goal is to guide instructors in developing an integrated, interconnected knowledge for implementing effectively ATM in their teaching.

## 4 Experience with the ATMF

Fig. 3 provides a graphical overview of the empirical studies conducted in several Greek educational settings to help formulate the proposed framework. This model consists of three interrelated levels: Initially the key characteristics that were researched for every empirical study are reported. Next, is shown the alternative teaching approach that was implemented for each study. Finally, at the bottom of this visualization, are presented the proposed framework's stages corresponded with the previous approaches and studies.



**Fig. 3.** A map of the empirical studies within ATMF.

All the studies described in this section, are all previously reported elsewhere in peer-reviewed publications and therefore are presented briefly.

### 4.1 Research study 1: Peer Learning

Initially, we conducted an experiment using Peer Learning and Collaboration techniques comparing them to traditional teaching, to secondary education students [17]. The learning from these techniques was assessed and students' attitudes towards the alternative teaching were researched through quantitative data ( $n=57$  students). In addition, teachers' opinions about that way of teaching and learning were explored through means of qualitative data. The empirical findings of this study confirmed the

positive effects of student-centered learning techniques at CSE. The study was used as an input during the design of the ATMF and provided evidence that the specific ATM had better learn results and increased motivation by learners.

#### **4.2 Research study 2: Social Networks in Education**

Secondly, we researched Social Networks (SN) for assisted learning, through an observational study with undergraduate students [18]. Facebook was used as a teaching tool in higher education and ways that SNs can be used in teaching and learning were investigated. Both qualitative and quantitative data were gathered ( $n=66$  students) through one academic term. The results reported that students were highly motivated to participate in the lesson through the Facebook page although there seem to exist some personalities, cultural and gender differences about the usage. This study was also used as an input for the ATMF while it confirmed the positive effects of SNs in promoting learning and motivation.

#### **4.3 Research study 3: Game-Based Learning**

Next, we examined the Game-Based Learning method (GBL), in order to teach basic programming concepts to primary school pupils [19]. The empirical findings of this study (quantitative data from  $n=94$  students gathered) confirmed the positive effects of GBL in promoting basic programming principles to young children. Empirical findings derived from this analysis provided valuable information games and pupils' satisfaction and willingness to use them for acquiring programming knowledge. In addition, Pair Programming method was students' choice for learning programming. However, the short activity of this study did not have long term results and motivation at children and thus the element of long-term planning was added to the ATMF.

#### **4.4 Research study 4: Physical Computing**

The empirical findings of this study demonstrated the importance of referring to alternative learning through the instructor's views. In particular Educational Robotics through a national competition was researched [20]. This observational study investigated the benefits of students' involvement with robotics about skills, motivation and learning through the teachers' eyes (a qualitative methodology was used  $n=18$ ). The results showed that there are numerous benefits for students: they increased their collaboration, problem solving and creativity skills; understand STEM concepts about CS and engineering and especially gaining programming knowledge. Therefore, the ATMF was enhanced with the instructors' perspective about the learners' knowledge and motivations.

#### 4.5 Research study 5: Personal Learning Characteristics

Finally, the empirical findings of this research identified different personality traits and especially cognitive style as an important factor in programming learning through serious games. This study investigated students' attitudes (quantitative data gathered from  $n=77$  students) from gaming activities to reveal the quality of their learning experience and correlated it with their cognitive profile to reveal potential differences [21]. In addition, through an empirical way it was revealed the GBL effectiveness and next it was compared to students' cognitive styles. Cognitive style was found to be a significant learning characteristic that should be taken into consideration when using digital games to learn programming. This study was used to finalize the ATMF and provided evidence that personality traits may affect both teaching and learning.

## 5 Conclusion

In this paper, we present ATMF, a conceptual framework for CSE that allows teachers to continuously experiment with and improve their teaching. The proposed framework is about student-centered teaching pedagogy trying to address issues around learning and teaching of CS concepts. The ATMF is implemented based on the perspective that learning is a socially embedded cognitive process and knowledge is socially constructed through interaction and activity with others. The main objective of the ATMF is to promote motivation and enhance learning. It proposes that this model can be used in examining instructors' CS lessons of any level and any context and in designing experiences for teachers on the integration of student-centered practices in CS teaching.

The proposed framework for teaching with the use of alternative methods can make teaching both more effective and more efficient, by helping create the conditions that support student learning and minimize the need for revising materials, content, and policies. While implementing these principles requires a commitment in time and effort, it often saves time and energy later on. However, more work needs to be done. We consider that the framework itself is robust and therefore it will not change. Likewise, we expect that for ATM some practices may change and new ones may be added.

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