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Proactive Independent Learning Approach: A case study in computer arithmetic

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Abstract. The rapid growth of knowledge and scientific challenges required lifelong continuous education in computational science and engineering. Computer numerical system representation and computer arithmetic are the basis of numerical computing of scientific models. In this work an adapted student centered and problem based learning strategy is presented. Development of problem solving, effective self directed reasoning and communication skills are promoted. A pilot study was conducted to determine the validity of the proposed alternatives. The study aimed to evaluate the performance of students to solve new problems and effectively describe the problems, the theoretical context and the possible solutions. Preliminary results are presented for a particular population from which the sample is actually drawn.

Keywords: Lifelong proactive learning, student centered learning, problem based learning, computer arithmetic, numerical methods, mathematical models.

1 Introduction

Graduates of computer science and engineering programs are expected to face scientific and technological advances. Computational science and engineering is a field that has a high rate of knowledge and technological change. Self-learning, creative thinking and communication skills are needed to solve problems in scientific research and industry [1]. Their acquisition is a gradual and continuous process. It allows the learner to be able to develop a proactive lifelong learning practice and critical thinking. The process of prior knowledge integration is essential to learn any scientific discipline [2][3]. Integration of previous knowledge is fundamental from the first year of any university course to advanced professional interdisciplinary areas in computational science [4][5]. It is a challenge for a teacher not only to develop their subject, but to promote and guide the students to develop these fundamental abilities [6]. It is necessary a framework that promotes knowledge integration and positive feedback [7]. Learning schemes in the first year of a graduate university program in computer science face a few common problems [8][9]. In particular, the quality of education in primary and secondary schools in Argentina has deteriorated in the last decades

[10][11]. As a consequence, first year university student population presents a profound lack of some basic skills expected to be developed in secondary school. The background knowledge heterogeneity is another fundamental problem reported in the national evaluation tests [12]. Any learning strategy to reduce the gap between secondary school and university in Argentina has to consider many factors. It is a complex phenomenon that is out of the scope of this article. Nevertheless, certain aspects have to be considered in any attempt to improve the way computer arithmetic is taught. The aim of this paper is to present an alternative learning approach to achieve specific objectives. Students are encouraged to have more control and responsibility over the learning process [13] in a deeper approach to learning. In particular fixed and floating point representation of numbers and computer arithmetic for model implementation are the main topic of the presented case study. It could be included in a course of computer organization, numerical methods or advanced computing modelling [14]. Results of a pilot experience that has been carried out with students of computer science and engineering are reported.

This paper is organized as follows: Section 2 briefly describes the main ideas behind the proposed approach. Section 3 presents the particular case study. In section 4 results are presented. Finally, conclusions and future works are given in section 5.

2 Proactive Independent Learning Approach

Important developments in computer science and engineering education in recent years has been oriented to Problem-based learning strategy (PBL) [15]. PBL was first applied in the Medicine School at McMaster University (Canada) as an innovative educational proposal [16]. Although it was successfully adopted by other prestigious medical schools like Harvard Medical School, the particularities and necessary adaptations to engineering and computer science programs remains an active research area. A traditional teaching scheme or traditional learning approach (TLA) involves theoretical knowledge first taught to the students. It is followed by practical lectures explaining how to solve problems applying the previously learnt theoretical concepts. Finally the teacher sets an exam to test the basic knowledge and skills acquired by the students. The main characteristics of TLA are to set the teacher as the transmitter of linear and rational knowledge and the student as a passive receiver defining a structure environment of individual learning. PBL can be defined as a learning environment in which the problem solving process involves searching for information and discovering the new knowledge necessary to tackle the problem [17]. It has been shown in the literature that PBL assists to gain skills in problem solving and lifelong learning abilities in contrast to short term surface learning. In a PBL approach, small groups of students work collaboratively to solve a particular problem, with no previous preparation, with the student being the center of the learning process, constructing knowledge as an active participant in a flexible and cooperative environment. The teacher guides and facilitates the whole learning scheme. The assessment is now shared among the student, the group and of course the teacher. PBL promotes self-learning, developing problem-solving skills, cooperative learning, and improving oral and written communication. An alternative scheme is proposed and named proactive independent learning approach (PILA). This alternative thread is related to problem based learning, active learning and lifelong learning [18]. It comprises a set of objectives, guidelines and constraints. It is not a set of strict steps to follow, but a flexible orientation, applicable to different learning contexts and approaches from TLA to PBL. The main objectives are to promote an active and independent attitude to learning. Independence and critical thinking are essential to develop a proactive approach beyond a particular course or career. Another central objective of PILA is to stimulates students to adopt lifelong and continued education. PILA encourage self discipline habits where learners become responsible for their own learning in university and beyond. No fixed guidelines are proposed, motivation and adaptation are keywords in PILA, both for students and teachers. It implies studying theoretical concepts on an individual basis, intensive practice on problem solving, writing technical essays, oral exposition and discussion of solutions. The proposed approach does not impose collaborative working as a requisite, or any other technique if for a specific student another one suits better. A fundamental step is to learn through solving problems, writing essays or other alternatives that need to integrate previous knowledge to be done. Certain constraints or boundary conditions should be addressed before any attempt to follow this alternative. One of the important constraints is the number of students, it requires relatively small groups if a team collaborative work is going to be adopted. Problems or projects need to be designed carefully involving many resources. A relatively common background knowledge of the students would be convenient as a prerequisite. It has been pointed out that a problem that requires high integration of previous knowledge is recommended from the beginning, reinforcing the main characteristics of the proposed approach. Nevertheless, if PILA is to be applied to a first year undergraduate level, gradual integration would be preferable. A gradual work example strategy [19] and progressive difficulty tasks [20] would be more convenient.

3 Case study: computer arithmetic

The computational and numerical modelling group at III-LIDI seeks to transfer the results of its scientific investigations and experience. In particular to improve teaching strategies in computational science and engineering related subjects [21][22]. The modelling group gathers experimental data of student performance in courses of: computer organization, numerical methods, machine learning, digital image analysis, statistical pattern recognition and digital signal processing. Encouraging excellence in a lifelong attitude towards continuous education in the area [23][24]. Computer numerical system representation and computer arithmetic are the basis of numerical computing [25][26]. A detail knowledge of numerical computer representation is necessary as a previous requirement for the implementation of any scientific numerical model [27][28]. Specific approaches to teaching computer arithmetic have been proposed [29]. PILA is proposed as an attempt to improve learning of these advanced topics reducing the knowledge gap between basic and advance courses by building solid fundamentals. A pilot experience was carried out with a sample size of 30 students in the experimental group (PILA) and 30 in the control group (TLA). The students were assigned randomly into each group. A detail selection of the 60 students was carefully done to ensure similar previous conditions in background knowledge. Four tests were conducted, named T1 to T4, to evaluate written expression, standard problem solving and integral type problem solving. Each test was evaluated with a scale from 0 to 120 points. The TLA and PILA students frameworks were based on a set of selected topics where students presented mayor difficulties to model and solve problems. The TLA group assisted a 3 hours formal lecture once a week and another 3 hour solving problems class a week. These students learned theoretical concepts and received instruction on how to understand and solve specific related problems. The second group, PILA, assisted also 6 hours a week. Each week an optional, but strongly recommended 2 hours lecture introduced the fundamental topics to cover and problems to be solved. PILA promotes proactive and self directed learning, but it does not impose any limit on the teacher active participation particularly giving feedback as it is required. Both for the experimental and control group optional tasks were proposed. Students were required to submit a description of the problem and a possible solution. In table 1 the characteristics of the groups for test and optional activities are summarized.

Computer Arithmetic				
Type of activity	Tests T1 to T4		Opt. team work	
Group	TLA	PILA	TLA	PILA
Students	30	30	6	6
Teams	-	opt.	2	2
Tasks	-	opt.	1	3

Table 1. Group Characteristics

Optional activities for the control and the experimental groups were suggested. PILA encourage the idea of self directed research in a long time basis, naturally reading and analyzing of diverse bibliography is essential in computer science. Table 2 presents the number of optional activities of each group. The PILA group was faced with a more general real problem, called integral task. The students were challenged to work collaboratively to solve this complex problem. In order to find a solution to the proposed problem they needed to build up the necessary body of theoretical concepts, search bibliography and organize the work among them. At the core of PILA is to respect and encourage to adopt different learning preferences, like working individually on the integration task. Finally, each group or individual student, had to present their results. The teacher guided the work, but the learning was centered on the student.

Optional activities	TLA	PILA
Suggested readings	6	6
Open optional tasks	1	3
Use of simulation tools	2	2
Collaborative working	1	3
Report presentation	1	3
Integral Task	-	1

Table 2. Number of optional activities

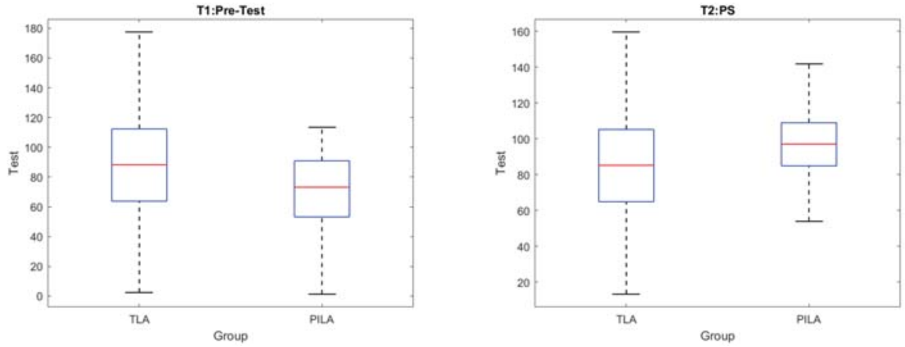
4 Results

The assessment scheme had three main parts: independent evaluation, comparative tests and a survey among students [30][31]. The tests were carefully designed not to alter the normal schedule of the course and not to overload the students subject to the experience with activities [32].

Groups	Test	Mean	SD	df	tvalue	pvalue
TLA	T1	86,56	39,23	58	1,69	0,0972
PILA	T1	72,13	26,12			
TLA	T2	83,79	32,52	58	1,81	0.0765
PILA	T2	96,28	19,53			
TLA	T3	73,81	35,52	58	2,19	0,0319
PILA	T3	88,31	15,62			
TLA	T4	67,14	28,61	58	2,53	0,0142
PILA	T4	82,93	18,67			

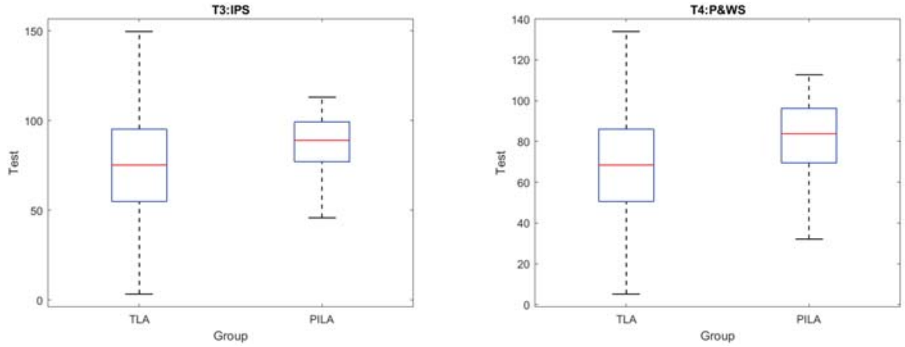
Table 3. Comparative tests

Table 3 presents the mean, the standard deviation and two sample independent t hypothesis tests for all the main evaluations. The null hypothesis is that there is no difference in the mean performance between the control and experimental group. T1 is a pre-test that attempt to verify the basic background and similar skills of both groups at the beginning. T2 determines the performance of the groups to find problem solutions of common types of problems. T3 explores the skills to solve new problems or integral problems. T4 is a global test that involves solving standard problems, integral problems and evaluating writing skills. No initial significant difference was observed between TLA and PILA neither in the pre-test nor in the teacher observations. Figure 1(a) shows the boxplots for the pre-test. Figure 1(b) shows the boxplots for the final evaluation on problem solving for TLA and PILA. Both groups solved the problems without significant difference.



(a) Pre-test (b) PS

Fig. 1. Pre-test and problem solving test



(a) IPS (b) PS-IPS-WS

Fig. 2. Problem solving and technical writing skills

Figure 2(a) shows the boxplots of TLA and PILA for the integral problem solving evaluation. Figure 2(b) shows the boxplots for the global evaluation on problem solving, integral solving and technical writing skills and communication. PILA group presented a significant performance difference ($p<0,05$) in T3 and T4.

Group	TLA	PILA
Open optional tasks	2	2,5
Use of simulation tools	4	4,5
Collaborative working	3	4
Report presentation	2	3
Worked example orientation	4	3,5
Optional integrating task	-	4,5
Overall learning experience	3	3,5

Table 4. Average marks from students opinion.

The information on students learning experience came from the teacher constructive communication with each group and from an anonymous questionnaire completed by the students. A list of statements was presented to the students of both groups. The scale from 0 to 5 indicate their agreement about the contribution to the learning experience from negative to positive respectively. The results are given in table 4.

5 Conclusions

This paper discusses a learning approach, particularly adapted to improve certain skills. It is based on PBL and shared many of its characteristics. The results of the presented case study indicate that PILA can be successfully applied for teaching and learning computer arithmetic at different levels. It has been observed that students in the PILA group were more motivated to develop proactive, independent learning skills. The analysis of results reveals that students of the experimental group displayed more effective abilities to solve problems that requiere previous knowledge integration. This study aimed at examining the effectiveness of an adapted approach on the performance of adult students. More extensive research needs to be conducted to analyze the performance on critical thinking, written and spoken communication. Further research may examine atypical values in the performance of students under different learning strategies.

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