Methodologies for developing Academic/Research Skills in Computer Science and Telecommunications Departments

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Abstract: Based on the demonstrated value of academic literacy and communication skills in academia and professional life, numerous experts, curricula designers and accreditation boards consider them integral in computer science curricula and value them as an important component in academic study. Although engineering education programs have kept pace with emerging disciplinary knowledge, research and technologies, they have been less successful in ensuring that their graduates acquire the skills, and attitudes desired by academia and the workplace.
More specifically, Computer Science and Engineering departments in universities in Greece focus almost exclusively on the "hard" skills, that is, the theoretical and technical subject areas, and ignore provision of support for the above-mentioned survival skills. An Action Research case study on engineering pedagogy was conducted at two departments of a university by means of a course designed to face the shortfalls for current generation of freshmen which is severe in Greek Universities and to fuse essential disciplinary needs, skills and knowledge in a module, by integrating it into the curriculum and contextualizing it to develop a novel course for Computer Science and Telecommunication undergraduate students; emphasis is laid on academic/professional skills, literacy and conventions specific to the scientific discourse community they have just entered through an integrated project-based approach to ensure active learning, engagement, enculturation, consolidation, collaboration and the teaching-research nexus. The purpose of this empirical investigation is to present the experimental findings of this integration, students' response, experience, challenges, and benefits, seeking to examine student understanding of academic conventions, and how well students transfer this learning to their projects. Data was collected through various research instruments and results reveal that students achieved substantial learning gains in academic skills and significant growth toward a more mature understanding of academic life, responsibility, ethics and integrity.

Keywords: Academic and Research Skills, Engineering Education, Project-based Learning

1 Introduction- Contribution/Statement of Purpose of this Dissertation

This dissertation captures and distils lessons learned through an empirical, experimental approach to developing skills and fulfilling key needs in engineering education.New requirements in engineering education concerning content and pedagogy, generates a growing concern about the imbalance between hard core and soft skills courses in many Engineering curricula, especially in Greece, as it deprives students from acquiring discipline specific conventions, enculturation and the teaching-research nexus, and graduates from work readiness and employability. It provides a proposal and empirical insight through the application of an eclectic methodology to address deficiencies and harmonise both instruction and content in Computer Science and Engineering Departments with European and International guidelines.
It is also a contribution to the exploration of the dialogue between research and practice in university education settings. The author speaks with involvement and from experience. An action research is applied to promote reflective practice, methodological innovation, understanding of academic and professional conventions, curriculum development/modification, institutional change and academic/professional development through skills acquisition.

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The motivation and background for this research is to bridge the academic/professional competency gap between the ability of computer science/engineering undergraduates and the current and future needs of academic study and the computer science/engineering profession.
Despite the official guidelines for US and Europe concerning academic/research skills, few degree programmes provide explicit help for students who do not already possess such assumed skills [1]. The problem is more intense in Greece with traditional lecture-based instruction and traditional end-of-semester written assessment prevailing across the curriculum eliminating thus chances of making provision for generic study/research skills, let alone specific key skills, tailored to the students' academic and future professional needs.
In this framework, we have identified as a priority this imperative need and have been inspired to take up Action Research to design a course to face the shortfall for current generation of freshmen (which is severe in Greek Engineering Departments) by shifting towards academic, discipline specific literacy, professional skills and transferable competencies and integrating them in the curriculum. This novel contextualised course which fuses essential disciplinary skills and knowledge and exploits current pedagogy and a suitable methodology will help students survive throughout their studies and compete successfully in the global workplace afterwards.
Similar research efforts devoted to this end have been reported at an international level. Unfortunately, in Computer Science departments' curricula in Greece, dedicated, specially tailored "academic skills" modules are out of the question. This leads to deficiencies that impede academic advancement and integrity as well as student socialization and satisfaction and will be discussed extensively further down.
In response to voices of concern about attrition rates, the increased demands to develop academic and professional skills before leaving university setting [2] and to the alarm by "the plagiarism plague" [3] along with the multiple deficiencies detected in contextualised writing across the Greek student body, this action research has been put forth. The result is an interdisciplinary effort that has been taken in developing an integrated course for a one-semester course for Computer Science and Telecommunication freshmen student to address deficits. Identifying the discrepancy between 21st century needs and actual instruction provided, helps us raise awareness and recognition of the value of these skills. A review of best instructional/methodological practices recommended and applied as suitable at both the level of delivering CS core/content modules and the level of teaching academic skills and literacy in Computer Science departments worldwide has made us contemplate on strong and weak points, design and apply an innovative integrated2 approach which is the case study presented in this work. In this course, groups of students go through the various steps to carry out an original research project as a vehicle to acquire specific needed skills and learn professional writing conventions common to research papers and academic life in their scientific field.

2 Literature review

In this section, a consideration of what the targets of Computer Science and Engineering Education should be and an examination of the concepts, learning theories and instructional methodologies which have been developed and applied to cater the needs of this discipline are presented. For a course to fulfil its aims, we need to know how university students learn, to understand barriers to students' learning, and to develop modern, tailored, in and out-of-classroom techniques that promote content learning and academic soft skills acquisition among students in Computer Science and Telecommunications departments [4].

Reports from worldwide experience present that a shift to skills is increasingly recognized and appreciated in Higher Education and the business arena. Modern education does not only involve knowledge, as in traditional education, but it also entails what the students are able to do with this knowledge (and how) [4]. The measurement of competences or learning outcomes should be an important consideration in the evaluation of an educational method or a course/degree [5].

A review on international literature on skills particularly required in Computer Science reflects that numerous voices coming from faculty staff, curriculum designers and potential employers emphasize the inadequacy of support for undergraduate and post-graduate students concerning soft or behavioural skills such as analytical skills, communication skills, teamwork, academic writing, critical thinking, problem solving, dealing with written and spoken academic texts, understanding use of technical literature and other scholarly information sources, self-learning and suggest shift and adaptation [6][7][8][9][10][11][12][2][13], [14–16]. Professional communication is an important aspect in the development of effective CS and engineering graduates.

As Computer Science is a rapidly changing field, students should also be prepared to survive, compete and succeed in this changing environment by providing them curricula that address lifelong learning and include

professional practice as components of the undergraduate experience. Training students to integrate theory and practice is a key skill in CS education [17]. Inevitably, this has raised awareness to science faculty across the country to transform curricula and their instructional approaches they select for their undergraduate classrooms.

Enrollment and retention of students in computing departments/courses is another concern as enrollment numbers seem to be declining and students drop out of these programmes [18]. Successful academic performance is important to retention and it requires more than innate intelligence. Studies provide evidence that skills and intrapersonal factors are essential in meeting the challenges of demanding computing curricula [19].

Researchers have also recognised the need for cognitive skills for successful computing professionals [20–22] such as creativity, self-efficacy, high-emotional intelligence.

It therefore becomes evident that there is a worldwide concern/call to apply an educational philosophy that promotes the development of modes (or habits) of learning that are skills oriented and produces students with the right mix of technical and soft skills [23] to meet both national expectations and international exigencies.

Since going through the steps of project completion cultivates higher order thinking skills [24] and research is becoming a collective enterprise in industry and academia, Project-based instruction is undoubtedly a suitable and highly effective model for the CS context. Besides, it is quite probable that computer science graduates will find themselves working as members of a research team during their academic or professional life [7] therefore having engaged in research and team work previously will prove fruitful.

3 Research methods

For this study, various instruments were employed to gather data in two stages of this action research process which are described underneath.

3.1 **Research methods- Diagnostic stage**

To identify and define the problem a four-fold preliminary research was carried out. Most parts of it are the results of preliminary research performed through questionnaires while one is secondary research:

Instrument 1:

A questionnaire (Part A) which was completed by freshers to examine learning styles, habits, strategies, needs, factors that facilitate learning, preconceptions, misconceptions, existing skills, attitudes, anticipations. This questionnaire was anonymous to ensure that students feel free to express their deficiencies, problems, difficulties without fear of being looked down or considered inferior, in case of low-performance or low-achievement students.

Instrument 2: A pretest (Part B, followed by a post test at the end of the semester) which attempts to investigate prior knowledge useful for the level of education they are just entering and elicit prior acquaintance and experience of academic skills. This will be used as a control.

Instrument 3: A survey (secondary research) was carried out to discover the balance between hard and soft skills courses offered in the various Greek computer Science departments' curricula.

Instrument 4: discussion groups with faculty members to investigate needs that they have identified over their years in the departments through teaching and interacting with Computer Science and Telecommunications students.

3.2 **Research methods- Main research (Therapeutic stage)**

In order to evaluate and measure students' satisfaction and effectiveness and identify strengths, limitations and possible areas for improvement of this experimental intervention reported on here, various metrics have been gathered and considered for the analysis presented in this study, such as project evaluation, students' satisfaction, students' performance in the posttest.

For collection and reaching of the types of data mentioned above, the following 4 strategies (instruments) have been employed:

Instrument 1: posttest data, that is the second part of the questionnaires distributed in the preliminary diagnostic research which was once again filled in by the same students on completion of the course, after taking up the new content and mode of instruction, to measure students' improvement through comparing/contrasting the pretest with the posttest.

Instrument2: a criterion-referenced test: evaluation of students' projects submitted at the end of the semester as a culminating activity of all efforts made through this 13-week endeavour. Students' projects were marked according to rubrics.Projects were obviously not anonymous since students had to be informed about their grades/performance and provided with personalised feedback (at the level of groups for group work).

Instrument 3: students' self-report. This sort of data was collected through the completion of a questionnaire that was developed and administered at the end of the semester, targeted to investigate students' satisfaction of the experiential design, process, material, blended methodology, skills acquisition and perceptions of classroom environment. Anonymity was the only option for this student survey instrument in order to give participants the freedom to evaluate the instructor and her choice of methodology in a sincere, fair and objective way.

Instrument 4: discussion with students, field notes and observations

4 Preliminary/diagnostic pilot research

The first stage of the Action Research, namely the diagnosis or problem awareness [25] is described and analysed in this chapter. This stage has shed light to the instructional/learning methodology problems and students' deficiencies, helped us formulate the subsequent research questions and provided insight about the action that needs to be taken. The preliminary research pertinent to the main research, was carried out through a questionnaire and a pretest (in the form of questionnaires that have been distributed to students of the undergraduate programme of the department of Computing and the department of Telecommunications, University of Peloponnese), as well as surveys, in order to locate problems regarding academic/research skills within the student cohort of Greek computing education, select the appropriate paradigm and design the course accordingly. The areas that we have focused on in this initial diagnostic study are:

1. The level of exposure (if any) to research skills in formal instruction (while at school and while at university) and the level of students' linguistic skills in the English Language
2. The level of plagiarism owing to the absence of research skills training
3. Computing departments' curricula analysis aiming to reveal the proportion of soft skills.
4. Students' perception about academic skills and their lack of proficiency in this area

The data collected through the four research instrumentsin the framework of the pilot survey (diagnostic stage) and their analysis are presented and discussed. This survey reveals the needs of undergraduate students studying in a computer science department in a Greek university regarding academic/research skills and leads us to decide on the appropriate principles that should pertain our course design and implementation in our setting.

It becomes evident that HE Institutions in Greece do not run skills courses or workshops either specifically designed for the department's content embedded in the curriculum or outside the undergraduate programme (generic).

Therefore, computing and engineering students do not receive formal instruction and training in academic literacy and professional communication at any stage of either their formal compulsory education or in the course of their degree - not even in their native language.

Student pilot questionnaires to investigate their prior knowledge and perceptions on issues involving academic/research skills along with a survey in the curricula of CS/Engineering Departments in Greece and in the level of plagiarism that is thriving and discussions with faculty members verify the deficiencies and guide us to the formation of the suitable research questions and selection of the appropriate way to deal with the shortfall.

In this empirical research, through an innovative programme that is designed and applied, the following **research questions** are attempted to be addressed:

1. Student satisfaction

a. How were the students accepting the particular learning model which combined thoughtful integration of collaborative learning, online and face-to-face interactions as well as project-based learning?

b. Why are students willing to attend, engage and participate in the course? Do they identify its beneficial effects?

c. What is the students' opinion of the learning experience, the problem-based methodology/process, the challenges posed and its effectiveness?

2. Can this course support learning and skills development? What does it provide to students?

5 Action Planning- Theoretical Course Design Considerations

The action planning that has been developed based on the findings of the diagnostic stage. It involves the intervention that has been planned/designed and its specifics in terms of an eclectic methodology. The diagnostic procedureshave revealed that new forms of methodologies need to be explored and new models of participant behaviour need to be considered in an effort to understand and cope with the problems and deficiencies. This is the stage to select which theory to put into practice, thus a consideration of the concepts and theories which suitably underlie the instructional methodology and teaching/learning procedure to be used in the exploratory stage will be made.

This integrated approach which we have termed as "Research Project-Based Approach" encapsulates the most effective elements of four currently acceptable theoretical and methodological bases that have been reported in literature and applied in classroom settings. The four pillars that determine the specifics of our experiment are: Genre-based approach, Project-based learning, Content-based learning and the Revised Bloom's Taxonomy. These four theories provide the foundations for the design and application of the experiment that will be conducted and will enable the researcher to test his hypothesis by reaching valid conclusions.These approaches are the most suitable considering the challenges and constraints posed by the framework of the Greek Computer Science and Engineering departments and actual students' needs as detected through our diagnostic survey by questionnaires.

6 Overview of the Experimental Procedure- Application & Technics

In this chapter, the 4th stage of the Action research, namely the therapeutic stage in which the hypotheses are tested by a consciously directed intervention or experiment in situ, is described.

This Action stage or experimental manipulation analyses the intervention that has been planned and performed in the form of a novel venture at the department of Computer Science and the department of Telecommunications, University of Peloponnese, Greece. The purpose is to provide students with academic literacy support and skills (the language of delivery being English) in order to treat the deficiencies and cope with the problems and inconsistencies with computer science education essentials as advocated by specialists and diagnosed by our preliminary research.

This section describes the activities/deliverables completed by students while taking the course and carrying out their projects in a collaborative way exploring the importance of establishing student-to-student networks (collaboration) in which they become active and willing participants. This stage can be seen as a clear description of their own transformative pathway towards skills acquisition and computer science and telecommunications content knowledge and provides useful insight for instructors that wish to adopt this methodology or enrich their teaching portfolio with new learning tools [26]. Of course, this approach requires certain degree of flexibility and dynamism from all involved [27], as there are demanding areas entailed such as defining an angle of a broad topic to form challenging project titles, laying out the process and steps of how learners should go about developing a project and presentation, time and in-group management, avoiding plagiarism and so on.

The new course was introduced in the first semester of both the department of Computer Science and Technology and the department of Telecommunications Science and Technology of the University of Peloponnese, Greece. All students had to take this obligatory credit-bearing course on "Academic/Research Skills", however, attendance was optional, as is the case with most non-laboratory based courses in Greek Higher Education. Students are invited to attend a 3-hour session per week, which is of a hybrid form in the sense that half of it comprises a core session in the lecture hall and, the remaining, of a lab session in the computer laboratory, and to engage in self-study, self-exploration and team.

Aims

The aim of both modes of instruction, namely core classroom sessions and computer lab workshops, was to help students develop two types of skills:

a. Specialised skills, tailored to their field of study such as researching a CS/Engineering topic, retrieving appropriate, scholarly resources, understanding specialised vocabulary, writing up an academic project, developing oral communication skills

b. Transversal, cross-curricular competences, such as group work, autonomy, responsibility, accountability, self-study, collaboration

7 Results and discussion

7.1 Posttest- Instrument 1

As we can observe after comparing and contrasting students' answers in the initial and final test, we can conclude that a significant improvement has been performed. Students have started to abandon their High School habits and familiarise themselves with academic texts and the new genre along with the conventions and ethics that apply. The new course therefore has fulfilled its purposes as the benefits that students have reaped are evident.

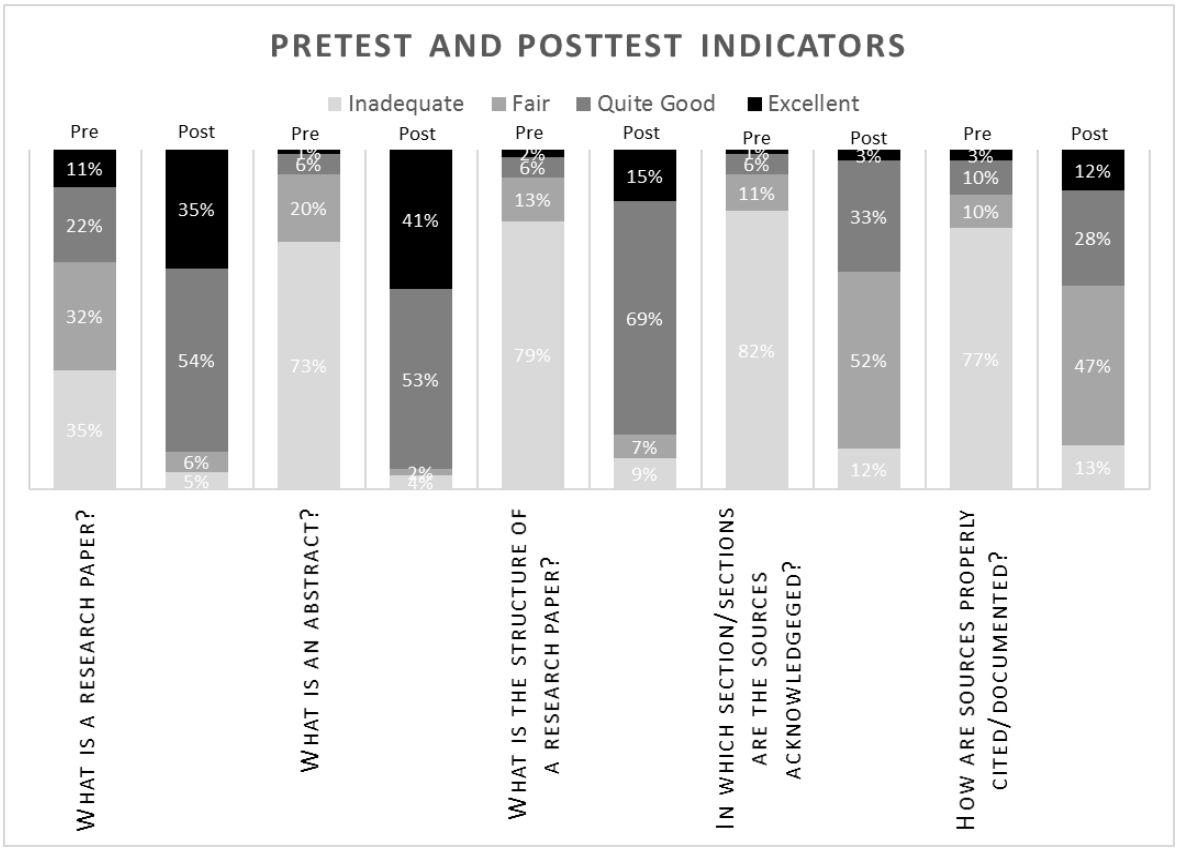

Fig. 1. Pretest and Posttest Performance Indicators

7.2 Criterion-referenced test (Project Evaluation)- Instrument 2

This study examined the results of the projects based on survey findings from projects of 72students of two departments. The results showed that the projects were successful in fulfilling the set requirements and in promoting students' academic engagement. The majority of students performing averagely in most criteria and above averagely in some other, is a significant predictor of academic progress. These findings suggest that study projects can potentially contribute to improving Computer Science higher education as they fulfil students' needs for competence, relatedness and autonomy and enhance students' academic engagement.

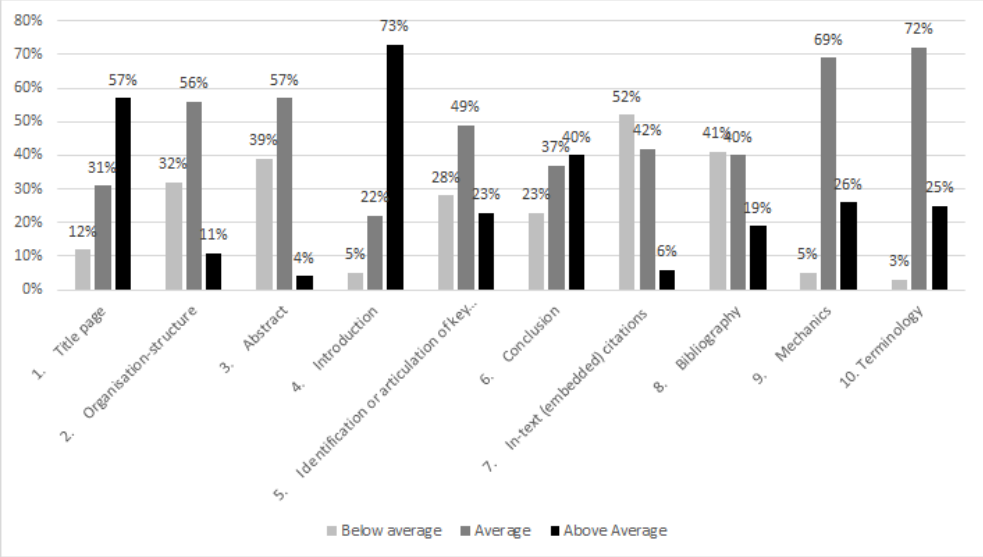

Fig. 2. Student performance towards the Academic/Research project requirements

7.3 **Student satisfaction- Course experience questionnaire - Instrument 3**

Finally, in the overall evaluation, this new learning methodology has been rated very highly by students. They appreciate the novelty-based motivation and challenges posed by this web-enhanced learning environment and would like to continue with this approach in other courses in the future. They liked the roles they assumed: a) as researchers brainstorming and specifying research questions, locating and evaluating resources and discovering information themselves b) as collaborators in the group allocating tasks, sharing information and the learning experience c) as authors producing an academic/research project about a state-of-the-art technology topic and d) as presenters performing in front of their peers for the first time.

Table 1: Aspects of the methodology that the students appreciated the most

Reason	Frequency (%)
1. The contextualized (genre-based) nature and Interdisciplinary mode	82%
2. Collaboration, group work	73%
3. The acquisition of knowledge and skills that will prove useful and transferable throughout their studies and professional life	57%
4. The fact that they were active learners and were invited to learn by doing	53%
5. Socialization with other students and smooth transition to the new academic environment	51%
6. The exposure to and exploitation of resources through the Internet and in the department library	50%
7. Innovation, originality	47%
8. The research, exploration and hands-on nature in the activities	45%
9. The fact that they learn academic/professional English discourse without realising it	43%
10. Having to study bibliography (internet sites, journal papers, books)	37%
11. The fact that they were encouraged to orally present their written project in front of audience (their peers) using IT (PowerPoint)	23%

7.4 **Summary of findings**

This content/project-based methodology can be considered an innovation in the curricula of Computer Science departments in Higher Education as it introduces a significant shift not only in the mode but also in the context of learning.

The empirical research findings, when combined with the practical advantages of integrating content and purpose-specific communication skills, provide persuasive arguments in favour of content & project-based instruction. The benefits for students are traceable in the instruments analysed about and are summarised in the following features:

1. project work focuses on content learning, in order to stimulate learners, enhance active engagement and responsibility and develop a sense of ownership in the process, by either selecting a suggested topic or an original one of their own, deriving from their discipline.
2. though the teacher plays a major role in offering support, guidance and feedback at critical moments in the process either during face-to-face instruction or on-line, this is a learner-centred approach because learners are engaged into active exploration, research, problem-solving, self-management and responsibility. Giving students freedom to immerse themselves in the project actively seeking information, relevant to the topic they are committed to examine, can lead to motivated and independent learners. The instructor inevitably relaxes control of the learners and assumes the role of guide or facilitator [28] as expected in the case of the interdisciplinary approach to integration [29].
3. eClass, and the Web in general, create a more vibrant environment for constructing/acquiring academic knowledge and soft skills, since they provide readily accessible variety of content resources. Sharing of information and documents, integration of ideas or information from various sources and collaboration are facilitated and encouraged. The "at- any-time" aspect of the Web is exploited since learners are free to access the platform and take up work at their own pace, anytime, anywhere convenient to them. Timetable difficulties usually prevent university students from attending on-site tuition. The lecture mode is not the unique way to acquire knowledge and cognitive abilities any more. Individualized needs are thus satisfied and certain categories of learners are facilitated.
4. a feedback loop is established between the instructor and the groups of learners (through drafting and redrafting projects and components of it). This feedback cycle may occur several times either in class or through the eClass platform before the final electronic submission of the project work encouraging students to stay current and alert.
5. the "one course for all" policy is abandoned. Uniform level education for everybody proved to be a wrong approach [30]. This project-based instruction applies customisation and user adaptation by making use of a combination of different backgrounds (High-school majors), different cognitive styles, different learning strategies, motivations, capacities, even hobbies and extra-curricular interest of students involved. It cannot be expected to receive final products of same level and uniform quality. Heterogeneity of the end-users -which is common in university classes - is not an obstacle since project-based learning meets the needs of learners with varying skill levels and learning styles [31] and is thus consistent with individualized learning and the socio-constructivist paradigm. After all, one of the important factors here is student engagement in the various steps of the process.
6. collaborative work over the completion of the project stimulates social interaction and contributes to the psychological adjustment of students to college life (enculturation), especially when the course is offered early in the beginning of their studies, as in the case presented here.
7. this approach culminates in an end product (e.g. a research essay and an oral presentation) that can be shared with others, giving the project a real purpose and situating authentic problem solving in an authentic physical and social context. The value of the project, however, lies not just in the final product but also in the process of working collaboratively towards the end point. Thus, research project work has both a process and a product orientation [32]. The atmosphere conducive for doing research is built, which is significant if we are to retain the bright minds.

To conclude, regarding the research questions in this thesis, we can say that students were very positive towards the innovative course as they achieve substantial learning gains in academic skills and professional communication and significant growth toward a more mature understanding of academic life, responsibility, ethics and integrity. The learning objectives were thus accomplished in order for students to reap the benefits and the education they receive be consistent with current requirements, building a rich understanding of themselves and their abilities and increasing their own self-confidence to perform the myriad tasks expected of them by potential employers.

8 Conclusions

As the results of the experiment show promising signs, this research is intended to inform practice, curricula decisions, instructional methodology and materials and contribute significant insights into Computer Science and Engineering education of both English and non-English speaking background computer scientists and engineers in Anglophone and non-Anglophone universities. The insights are relevant, significant, interesting, and have the potential to inspire and impact practice within the wider computer science and engineering education community. The methodology is informed by relevant theory and clearly demonstrates how the problem is approached and the design and application are developed accordingly.

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