Encouraging Students into STEM Related Disciplines

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1. Introduction

The UK government and Higher Education Funding Council for England (HEFCE) are currently aiming to reform education among 14 to 19 year olds, and higher education (HE) plays a vital role in the success of such a reform. In [1], it has been determined that there is a low participation in education in post-16 year olds and therefore the reforms aim to create opportunities for all young people to continue learning until at least the age of 18 and to give them the qualifications and aspiration to progress to third level education.

This paper discusses the implementation of an 'Introduction to Programming' course for pupils in their last two years of secondary school. The course will address fundamental programming concepts using Java as a learning tool, in a fun and engaging way providing Year 13 and 14 pupils with sufficient knowledge to help them make informed decisions on undertaking further study and pursuing a career in Science, Technology, Engineering and Maths (STEM) related disciplines, thereby improving retention within the subject. The implementation of the course is part of a funded project called Widening Access by Introducing Programming in Schools (WABIPS) in Northern Ireland, UK, which seeks to give the students a feel for the types of activities related when studying STEM subjects in HE, aiming areas in Northern Ireland that are not currently actively targeted by outreach activities.

The design of the 'Introduction to Programming' course is framed under contemporary educational theories which seeks an active participation of the student in the learning process by discovery assuming that learning is not determined entirely by intellectual capacities but it is also the result of the interaction with the environment [2]. The environment in the classroom provide the option for the pupils to find the relationships and coincidence of the presented contents through continuum challenge to solve different problems while at the same time encouraging the social interaction as a key factor in learning. Recent analysis demonstrates that the course is having a positive effect in that, firstly students are applying for computer science related courses based on having participated in the project even though they had not previously considered this as an option for their future. In the remainder of the paper the course contents and pedagogical strategies are discussed in Section 2, a review of the course assessment and statistics are presented in Section 3 and finally, Section 4 concludes the paper.

2. Course Contents and Methodology

The 'Introduction to Programming' course has two modalities. In the first modality, intended for local schools, the course is delivered on a weekly basis during an academic year distributed on two short sessions a week. The second modality is delivered over a three-day period as an intensive workshop during academic breaks, attempted to areas further away from the Magee Campus of Ulster University. The topics covered by the course are part of a regular introductory module, which contains fundamental concepts such as variables and variable declarations, input/output techniques, conditional statements, loops and arrays.

Under the framework of contemporary learning theories, the 'Introduction to Programming' course is constructed making the student motivation as a central pillar of the process. During the sessions, the small lectures, contents, the proposed exercises and challenges are considered as a source of motivation. If any course can engage a student into being motivated, it is possible to construct a smoother transition from a simple acquisition of knowledge to a real incorporation of new ways of thinking into the internal cognitive structure. The course must generate intrinsic motivation coming directly from the subject, in contrast to extrinsic motivation as a result of external aspects of the teaching-learning process such as the ability of the instructor to deliver the contents [4].

The rationale of the course assumes the participation of active subjects in the process of learning. The student is initially faced with a simple programming concept thorough a short presentation delivered by the course facilitator of no more than 20 minutes where an introduction for a new topic is presented in the form of basic concept and the programming syntax to use the new tool, in addition to a

programming example. At first, the student's perception of the new topic should be that it is understandable and achievable to generate the required motivation for the student engage in a second more active part, which involves an exploration of methods to solve problems and find the answers by themselves. Learning programming and algorithmic thinking poses an important challenge - pupils may not have faced the challenge of finding the solution of simple problems as a sequence of logical steps. Sometimes at HE levels, students can lose track from theoretical sessions to practical laboratories even within a couple of days. To overcome the situation, the students are faced after the initial presentation of concepts, with challenging problems that might be solved by different means depending of the level achieved. For example, similar exercises are proposed at different stages in the course, seeing how they become easier to solve as new concepts are incorporated. Successive exercises incorporate elements of previous exercises and past sessions to allow the pupils to construct an incremental internal scaffolding [3] with a global view of the programming tools and skills recently acquired providing a connected roadmap reasserting concept acquisition, by engaging in memory processing and inter-relational conceptualization. The exercises are designed to provide a logical meaning to the new concepts aiming to allow the students to think and analyse the possible solutions using the recently acquired tools.

The course also contemplates the incurrence of errors, and attempts to allow the student to analyse and share their concerns with their peers around them, encouraging peer assisted learning. The instructor usually engages in a discussion on how to solve the problem rather than to provide an explicit solution of it. An upper level as an active subject appears for some pupils when they are able to help their peers in solving the proposed exercises. This role of guidance is also encouraged by the instructor. Promoting an open collaborative environment, the learning becomes a matter of a group effort instead of only a personal challenge. The students will be aware of the progress of their peers, and a derived levelling is achieved in this matter. Through the development of the sessions, we have observed that the whole group typically advance at relatively the same speed, solving approximately the same amount of problems in a single session. At the same time, those that lose attention will easily re-engage in the development of the exercises. The social aspect of the course allows the emergence of cooperative learning, not as a deliberate selection of group activities, but as the result of allowing the students to engage in discussions on how to solve the given problems. The effort of the instructor and the students is focused on the acquisition of meaningful learning rather than in a competitive approach given by quantitative measure of grades and marks, where learning is perceived as a shared responsibility resulting in more efficient time management during the sessions. The model of the course poses the responsibility of learning in the student more than in the instructor.

3. Course Assessment

Both formative and summative evaluation of the course are developed, with both pupils and teachers (if appropriate) in the targeted schools. Formative evaluation will be carried out through questionnaires and informal conversation. This feedback enabled the instructors to make any necessary changes to the programme.

A further evaluation is performed by following the progress of the students who complete the course, as appropriate. The course is aiming to introduce programming to these students in order to provide a sound basis for a decision for further study in STEM related subjects, thus decreasing the non-continuation rate among such students. The success of this can be evaluated summatively throughout the further academic years by analysing the module marks and continuation rate of entrants that have participated in this project. This provides one basis for measurement of the success of the course. This analysis is ongoing in the current funded project whereby the former students are mailed to obtain feedback on where they are now studying, what they study, the impact of the course on their career choices etc.

The course for pre-university students has been on-going since 2010. In total, approximately 400 students have attended the course with a gender distribution of 61.76% males and 38.24% females (*Figure 1-a*). Among the students 23.53% students are already in a university, while the remaining 76.47% of students are still in the school/college (*Figure 1-b*). Among the students who attended the course that are already in the university, 62.50% are in Ulster University and the remaining 37.50% are attending in Queen's University, Belfast. There were no students attending any other universities.

Among the students who are already in the university, 75% are studying a computing related discipline, while the remaining 25% have selected different subjects such as music, media studies, and geography (*Figure 1-c*), 87.50% suggested that they have been benefitted from the course (*Figure 1-d*). For 56.25% of these students, the decision to study at a university has been influenced by the course. Among the students who are not yet enrolled in a university, 32.69% think that the course has impact on their current subjects and among these, most students suggested that the

course has helped them in ICT course work (*Figure 1-d*). Among the students who have not yet enrolled in a university, 88.46% will be applying to a university very soon, and the questionnaire implies that 52.17% of them will be applying to Ulster University, and 45.65% have Ulster University as their first choice for higher education. Overall, among these students, 50% suggested that the course has influenced their choice of the main subject to study at the university. From the students that will apply to university soon, 58.70% suggested that they will be applying for a computing related main subject, 4.35% may apply for a computing related subject and the remaining 36.96% will be applying to other subjects.

Among the total population of pupils that have attended the course, 95.59% suggested that they will recommend the course to be conducted in further academic years. Particularly, 93.75% among the students who are already in a university and 96.15% among non-university students will recommend the course to be conducted in the following academic years. In general, the course has been well evaluated by the pupils, and more than 95% of students suggested that they will recommend the course for the next academic year.

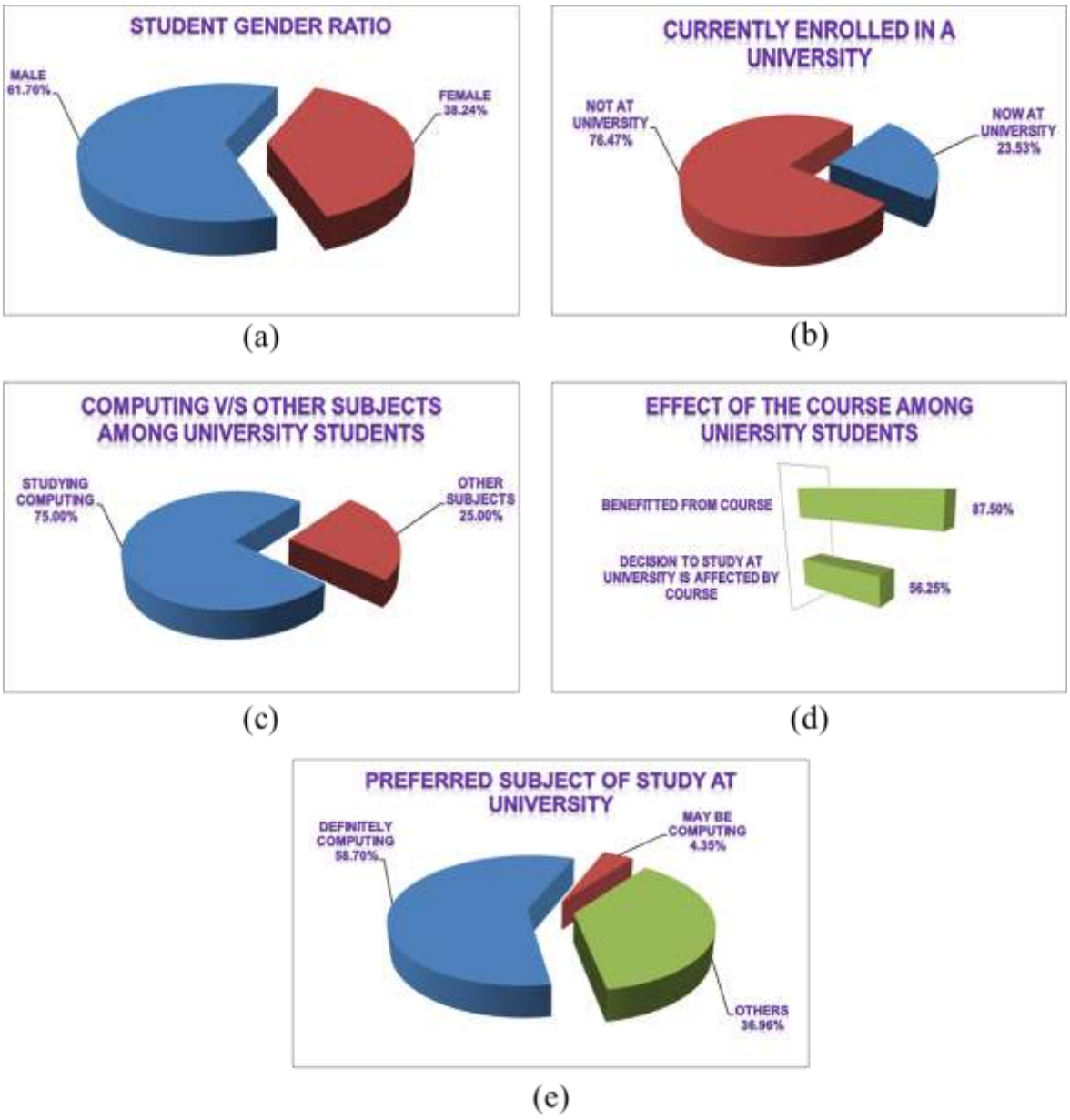

Figure 1. Java Programming Course Statistics. (a) Students' gender ratio; (b) Current situation of former students; (c) Computing related subjects vs. Other subjects in former students; (d) Effect of the course among former students; (e) Preferred subject of study at university level

4. Conclusions

The project discussed in this paper aims to encourage participation in STEM related subjects at HE from students from sections of society which have not traditionally benefitted from or have low participation in higher education, raising aspirations and attainment by introducing Java programming into secondary schools to teach the students new skills, thereby enlightening them that they are capable of studying challenging topics, giving them confidence in their ability to do so and inspiring them to strive towards higher education. In addition, it has been established stronger links with STEM subject teachers and careers teachers within the targeted schools.

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