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A Review of Interventions to Recruit and Retain ICT Students

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Abstract—This article reviews and analyses the educational research literature on interventions to increase the recruitment and retention of information and communications technology (ICT) students. The results show that three changes in computing pedagogy characterize successful interventions, and consequently offer promising ways to attract and prepare more people for careers in ICT. The most important selection criterion considered when choosing papers to review was that interventions had been tested in practice and their effectiveness measured. Interventions were arranged into two groups: recruitment and retention. Recruitment interventions described initiatives to motivate interest in computing among secondary schools students, whereas retention interventions described efforts to retain students in ICT majors at universities. The three pedagogical approaches that emerged from an analysis of the successful interventions were: (1) visual programming environments to teach introductory programming, (2) inquiry learning activities to engage students in computing, and (3) integration of interdisciplinary knowledge to attract students from diverse disciplines. This review draws attention to innovative teaching practices currently shaping computer science education. Wider adoption of these pedagogical strategies has the potential to significantly increase the number of qualified ICT professionals.

Index Terms—Information and communications technology, ICT, computer science, recruitment, retention, pedagogy.

I. INTRODUCTION

The ICT (information and communications technology) sector across the world is considered to be an important generator of jobs and economic opportunity. Broadly speaking, ICT encompasses computer-related disciplines and is distinguished by an emphasis on creation, not just use, of computing technology. However, an estimated shortage of qualified ICT professionals in places like Australia [1], Canada [2], Europe [3], and the United States [4] has stirred concern in developed nations that unfilled ICT jobs will diminish their economic competiveness. The rate of degrees granted to computing-related majors in the U.S. is currently inadequate to satisfy the predicted growth in the ICT workforce [5]. Thus there is a need to increase the number of students pursuing ICT studies.

In addition, there are worries that incoming university students are ill-equipped to learn computing due to poor preparation at secondary schools. A study analysing K-12 computer science education between 2005 and 2009 reported a decline in the number of advanced placement computing classes offered at high schools [6]. Recently, the world’s largest software company—Microsoft Corporation—warned that K-12 students in the U.S. are insufficiently prepared to pursue careers in computing [7]. The apparent weak state of computing education at secondary schools and the underproduction of computing-related degrees at the higher education level requires that the educational community find and implement effective interventions to attract and prepare more students for ICT careers.

Aside from industry demands for more ICT workers, educating more students in computing is a way to develop ICT skills that from a wider perspective can be considered to be fundamental in our modern knowledge based society. Wing (2006) [8] argues that computational thinking is a universal reasoning skill that offers unique problem-solving approaches in today's technology enhanced world. Computational software has increasingly become an indispensable tool in biology for genome sequence [9], in chemistry for molecular dynamics simulations [10], in quantum physics simulations [11], and in a host of other natural science disciplines. Newer disciplines such as the digital humanities are also starting to apply computational methods [12]. Therefore a diverse range of students can benefit from higher levels of sophistication with computational tools. Unfortunately, surveys indicate that many students perceive computer science as "boring" and "difficult" [13, 14], and that female students are particularly discouraged by uninviting male stereotypes [15]. These negative perceptions of computing severely limit the number of students learning computing skills or pursuing ICT careers. An all-inclusive digital society where people are empowered by computing knowledge to construct creative solutions should be a central goal in education [16].

In response to the negative trends in computing education, some authors in the ICT educational community initiated interventions to recruit and retain ICT students. Computer science departments were particularly eager to test interventions after experiencing years of steep enrolment declines. The aims of the interventions were to generate interest in computing and improve the learning process for students studying computing. The successful interventions were able to positively influence attitudes towards computing, increase student enrolment in computing classes, and improve retention rates of students studying ICT.

In this paper we review interventions applied by the educational community to recruit and retain ICT students. The originality and value of this review is that we focus only on evidence-based examples of interventions, and synthesize a simple list of three important categories to describe successful strategies for recruiting and retaining ICT students. Recognizing these categories will help the educational community re-design the computing curriculum in order to attract and prepare more students for ICT-related careers.

The general organization of this article proceeds as follows. First, Section 2 describes the search method to find research articles on interventions for recruiting and retaining ICT students. Then Section 3 summarizes the results of the recruitment and retention interventions. Subsections are used within Section 3 to arrange the interventions described by the different research articles into similarly themed groups. Section 4 presents the three pedagogical approaches in computing used to categorize the successful interventions and discusses the significance of these approaches. Also discussed in Section 4 are the limitations of researching and studying the topic of interventions to recruit and retain ICT students. Finally, Section 5 concludes the article with a brief summary.

II. Methodology

The search method to find interventions describing recruitment and retention of ICT students relied on the Thomson Reuters Web of Knowledge and EBSCO Discovery databases to locate peer reviewed scholarly articles. Combinations of the following search terms were used to find relevant articles: information communication technology, ICT, information technology, IT, computer science, education, student, school, university, career choice, career orientation, enrolment, intervention, initiative, dropout, recruitment, outreach, and retention. In practice the search process began with a smaller set of terms that was gradually enlarged based on examination of the preliminary articles found. Thus no single search using all the search terms at once was made. Instead multiple searches were performed as the search terms were refined over time. However, a combination of keywords that approximately captures the overall search process using Boolean operators is: (information communication technology OR ICT OR information technology OR IT OR computer science) AND (education OR student OR school OR university) OR (career choice OR career orientation) AND (enrolment OR intervention OR initiative OR dropout OR recruitment OR outreach OR retention). The actual searches generated results from the databases that could be comfortably examined (i.e. tens to a few hundreds of article matches rather than thousands of matches).

We set criteria to limit the number of articles included in this review. The most important selection criterion was that articles had to describe an intervention tested in practice and include some form of empirical evaluation. Another selection criterion was to restrict article publication dates to range from 2003 to July 2013 to maintain a contemporary perspective on the issue. Recruitment and retention interventions were separated from one another under the assumption that recruitment should aim to influence younger, pre-university students who have not yet committed to a career choice. Hence articles on recruitment interventions target only secondary school students, whereas articles on retention interventions apply only to university students.

Article titles and abstracts from the database search results were examined for relevancy using our selection criteria. When these failed to provide the necessary details then full articles were read. Typical database searches generated tens to few hundreds of article matches but an overwhelming number did not meet our selection criteria. A common feature of many excluded articles was that they focused primarily on gathering survey data about the perception of computing or the ICT field. This survey data was at times part of research looking into topics such as gender differences, self-efficacy, or social support. Although the articles may have suggested possible interventions, they did not validate those suggested interventions with experimental testing and were therefore excluded. Other non-relevant articles generated by the keyword search process included papers on business practices in the ICT workplace or the application of ICT in teaching. Articles from the database searches that matched our selection criteria provided a first set of 11 papers to include in this review. A second set of 3 papers was obtained by examining the references of the first set. The ultimate result of our search process was a compilation of 14 articles.

III. Results

A. Recruitment Interverntions

Interventions to recruit secondary school students to the ICT field are reviewed in this section. The recruitment interventions sought to increase enrolment in computing classes and motivate interest in computing. There are four subsections organizing discussion of recruitment interventions: visual programming environments, inquiry-based activities, organized day events, and teacher professional development.

1) Visual Programming Environments

Two articles describe recruitment interventions that applied visual programming environments (VPEs) to introduce and engage high school students in computing.

Cooper, Dann, & Harrison, (2010) [17] describe an intervention where a VPE named Alice was introduced into ten U.S. high schools. The Alice software allowed students to create animated stories and simple computer games while teaching them fundamental programming concepts. In contrast to a traditional programming language where a computer program typically outputs numbers and characters, the Alice VPE outputs visually appealing objects moving in a 3-D (three-dimensional) virtual world. The visual movement of objects provides immediate feedback to students about the functionality of their programs. Moreover, the implementation of programming code in Alice differs significantly from traditional methods. In Alice, programming instructions are inserted by a graphical drag-and-drop operation rather than by typing statements into a text editor. This graphical method avoids the possibility of cumbersome syntax errors that are known to discourage novice programmers.

Cooper et al. [17] reported that the intervention with the Alice VPE resulted in a significant increase in students taking the advanced placement computer science exam (compared to no increase for students at the national level). In one school, enrolment in the advanced placement computer science course jumped from 9 students to 33 students in two years.

Carbonaro, Szafron, Cutumisu, & Schaeffer (2010) [18] studied an intervention where students in an English Literature/Composition class at two Canadian high schools participated in a workshop to experience computer game programming. A VPE was used to create game adventure stories and also made use of a simple drag-and-drop graphical interface to insert programming statements. The authors evaluated the intervention through a survey that revealed a majority of males (69%) as well as females (57%) expressed a desire to create more interactive computer-based stories in school. The authors argued that storytelling with a VPE may be an important element in attracting more female students to the computer science discipline.

2) Inquiry-Based Activities

Two articles examined the impact of inquiry learning activities to motive interest in computing. The inquiry learning method relies on active construction of knowledge through discovery and scientific investigation. Hands-on experiments are often a crucial part of inquiry.

Rursch, Luse, & Jacobson (2010) [19] describe an intervention where inquiry-based activities were used to attract high school students in the U.S. to information technology. A two-day competition was organized at a university campus to bring together students from different high schools. The students were given learning materials to prepare in advance for the competition. They formed teams that met during extracurricular hours at their respective schools to practice. The activities at the competition included designing a computer-based educational game, building and programming a robot, and configuring a secure computing network to defend against cyber-attacks. Participation at the competition consisted of 213 students from 25 high schools grouped into 46 teams. The authors assessed the intervention with a survey of participants. A large majority (80.8%) responded that the activities made them more aware of professional opportunities in ICT and 85.4% said that the activities made them more interested in learning about ICT.

Ryoo, Margolis, Lee, Sandoval, & Goode (2013) [20] discuss an intervention to attract underrepresented minority high school students in the U.S. to computing using inquiry-based computing courses. The intervention lasted from 2008 to 2012 with over 2000 students enrolled by 2012. The students engaged in a number of activities which included building websites, designing computer games, and programming robots. The authors pointed out that the inquiry-based approach allowed students to relate their personal lives with the activities. For example, one student constructed a computer game that reflected on her sister’s experience with chemotherapy. A survey evaluating the intervention showed that over 70% of students had a positive attitude of the activities. The authors argued that a successful component of inquiry is that students can connect computer-based learning with relevant personal life experiences.

3) Organized Day Events

Two articles examined extracurricular events to attract students to computing that lasted in duration up to a few days. However, the cost in terms of effort and time expended by the organizers may have exceeded the potential benefits offered by a these short-term events.

Huggard & McGoldrick (2006) [21] describe an intervention in Ireland to organize a three-day event to attract high school students to technology based careers. The event attracted over 100 students and included a collaborative project where students worked in small teams to build and program a robot using the Lego MindStorms educational platform. Students without prior programming experience were able to create sophisticated programs using a VPE with a graphical drag-and-drop interface. Feedback from a questionnaire was used to evaluate the intervention. The questionnaire data from 66 students indicated that 86% felt confident in their ability to program the robot and 30% expressed a strong consideration to major in computer science after the event. The authors mentioned that the people committed to organizing the event (three academic staff members, two technicians, and six postgraduate assistants) worked long and demanding hours to prepare and manage the occasion.

Craig, Lang, & Fisher (2008) [22] studied large scale events in Australia designed to attract more females to ICT careers. At some of these events more than 1000 girls per day attended. These events offered opportunities for girls to listen to speakers and seek-out information on ICT careers. Nevertheless, from 2002 to 2007 female enrolment in ICT-related fields declined by 56% at Australian universities and the authors were unable to positively assess the effectiveness of the large-scale organized day events. Planning and running the events relied mainly on the volunteer efforts of university staff and outside professionals. The authors mentioned that one of the events was discontinued because "the academics who voluntarily conducted the program were no longer convinced the program was having enough impact to outweigh the enormous time commitment required to ensure the program operated well" (Craig et al., p. 350 [22]).

4) Teacher Professional Development

Coinciding with recruitment interventions was sometimes a complementary intervention to prepare teachers to implement the main intervention. The Cooper, Dann, & Harrison, (2010) [17] intervention listed under the visual programming environments subsection and the Ryoo, Margolis, Lee, Sandoval, & Goode (2013) [20] intervention listed under the inquiry-based activities subsection both emphasized the importance of providing teacher training. Two additional articles specifically focused on the impact of teacher professional development.

Cooper et al. (2011) [23] describe an intervention to train more than 100 middle and high school teachers to learn the Alice VPE. Teachers were introduced to how the Alice software uses computer graphics, animation, and storytelling to motivate interest in computing. At least 120 contact hours were provided to teachers. The authors noted that more than 80% of the teachers who participated in the professional development program continued to use Alice in their classroom in subsequent years.

Burrows, Borowczak, Slater, & Haynes (2012) [24] described an intervention to train pre-collegiate teachers to use a robotics platform. This professional development program aimed to raise the confidence level of teachers encountering new technology. The authors argued that teachers who are confident with technology are more likely to initiate classroom activities that have the potential to attract students to computer science. A survey showed that before the intervention nine out of thirteen teachers (69%) ranked themselves as novice in STEM and computer programming, whereas after the intervention the number dropped to zero. The authors concluded that teacher confidence impacts their ability to motivate students into careers such as computer science and engineering.

B. Retention Interventions

In this section articles describing interventions to retain university students in ICT studies are reviewed. The successful interventions show improved enrolment numbers when compared to previous years or when compared to control groups that did not undergo the intervention. Three subsections are used to group the retention interventions: revised introductory computing class, social networking, and computer game development.

1) Revised Introductory Computing Class

Three articles discuss interventions to retain computing students by revising the undergraduate introductory computing class. A rigorous and unexciting first-year programming class is often stated as the reason university students discontinue studies in ICT. Revising the introductory programming class aimed to engage students in computing and simplify the learning process.

Moskal, Lurie, & Cooper (2004) [25] describe an intervention to improve retention of undergraduate computer science majors by introducing a programming class that used the Alice VPE. A total of 107 students were studied in this intervention and the data was averaged over a two year time period. The Alice VPE eases the learning curve for incoming university students without prior programming experience or a strong background in mathematics. The authors studied retention of students in a rigorous programming course depending on whether students first took the Alice introductory programming class. They report that treatment students (i.e. those who had completed the Alice class) were retained at 88% whereas control groups (i.e. those who did not take the Alice class) demonstrated 75% and 47% retention rates (the control groups were separated based on high or low levels of programming and mathematics experience). These results are important because they show that students with low prior math and programming ability who took the introductory Alice programming class were even retained in the later rigorous programming class at a higher percentage (88%) than students with high levels of prior math and programming experience but did not take the Alice class (75%). The authors concluded that students with weak programming and mathematics preparation benefit significantly from a revised introductory programming class using a VPE such as Alice.

Alvarado, Dodds, & Libeskind-Hadas (2012) [26] studied an intervention that revised the introductory computing course at Harvey Mudd College in the U.S., and in part resulted in increasing female computer science majors from near 12% to around 40%. The new introductory course placed more emphasis on problem-solving using computation rather than technical proficiency with a traditional programming language. A popular final project in the class was to design a 3-D computer game. Furthermore, the class included an option for students to focus coursework and projects around the discipline of biology—an incentive for life science students to study computing. This interdisciplinary option integrated authentic biological data into programming assignments. The authors recommended relating computing to other fields such as the life sciences as a possible way to attract more women to study computer science.

Rizvi & Humphries (2012) [27] discussed an introductory undergraduate programming course using the VPE Scratch. The Scratch software allows students to construct a computer program by graphically connecting blocks of commands. Concepts such as variables and arrays are also supported by the Scratch environment. The authors studied how Scratch could improve retention of students in computer science with a weak background in mathematics. The results showed that after four years the retention rate of students who participated in the intervention was 40% whereas the retention rate of control group students was 31%.

2) *Social Networking*

One article described a retention intervention involving a short-term event for new students in computing-related studies to socialize with one another.

Talton, Peterson, Kamin, Israel, & Al-Muhtadi (2006) [28] describe an intervention for incoming computer science undergraduates to participate in a supportive social event. The event involved small teams competing to solve clues while exploring different locations on their university campus. The intent was for students to collaborate in groups and become active participants in computer science department events and organizations. A survey of participants showed that most expressed positive views of the activity and membership in department organizations increased compared to prior years. After one year, their data indicated that 79.4% of those who participated in the event remained in the computer science program compared to 65% of non-participants. The authors argued that social support networks help dispel the stereotype that computer scientists are antisocial.

3) *Computer Game Development*

Two articles describe retention interventions that connect computing to computer game development. This option presents students with the flexibility to pursue interdisciplinary studies while also acquiring technical mastery in computing.

Zyda, Lacour, & Swain (2008) [29] describe an intervention to introduce a degree option in computer game development at the University of Southern California. The authors discussed how a modified computer science curriculum could still retain a rigorous education in programming and software development while incorporating an appealing gaming option. This new degree option integrated elements of creative design and cross-disciplinary knowledge. Even students from interactive media, animation, and fine arts enrolled in game development courses along with computer science majors. The creation of the games degree program increased the number of incoming undergraduates majoring in computer science from 36 to 48. Half of the incoming students were enrolled in the games degree option. Retention of computer science students in the games degree option after their first year was 77.8% compared to 81.2% retention of the students in the traditional computer science option. The authors note that this data was from the first group to enter the games degree option as freshman.

Roden & LeGrand (2013) [30] describe a program in computer game development at Angelo State University that nearly tripled enrolment in computer science over a four year time period. The authors argued that an early course in game development emphasizing creativity and practical applications of computing helps motivate students to complete rigorous courses later in the curriculum. Retention of first-year students majoring in computer science (i.e. the freshman-to-sophomore retention rate) increased by a relative 10% after two years from the start of the new game development curriculum.

IV. Discussion

Our search for interventions to recruit and retain ICT students was deliberately limited to articles that described empirically tested interventions. Originally we planned to conduct a meta-analysis but the results of our search did not reveal relevant papers with effect size measurements. Most of the research papers originated from computer science educators at universities and did not provide the strict control group comparisons and effect size statistics that are found in social science research. Considering that several interventions involved relatively small numbers of participants it would be useful for future researchers studying the topic of ICT recruitment and retention interventions to calculate effect sizes.

Restricting articles to interventions tested in practice limited the amount of articles that were reviewed.

Nevertheless, the small number of articles still allowed us to analyse similarities and synthesize a list of categories to summarize the general features of interventions which positively impacted the recruitment and retention of ICT students.

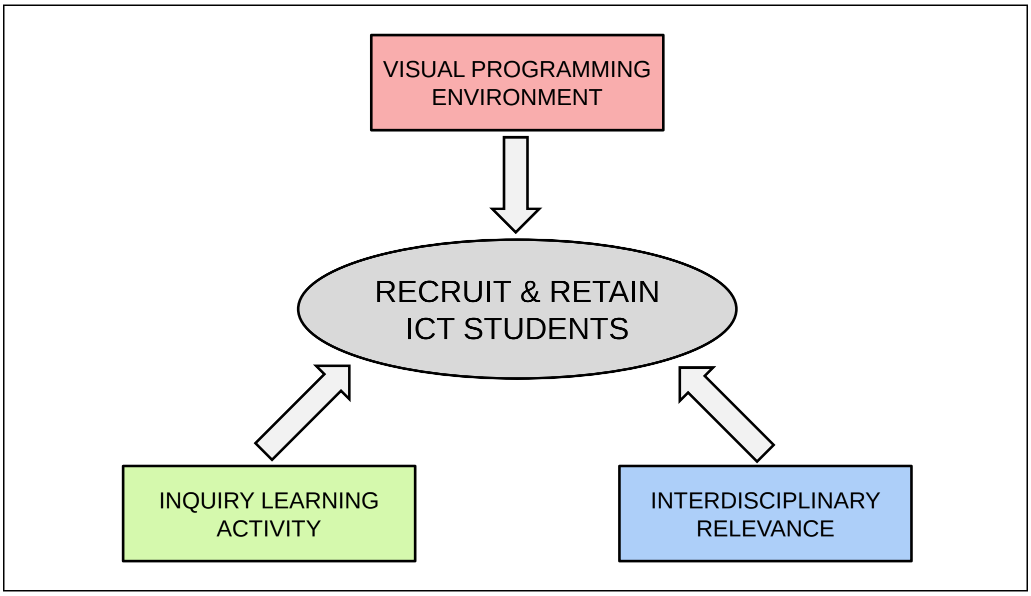

Fig 1: Three major categories that describe successful interventions to recruit and retain ICT students.

A. Three Changes in Computing Pedagogy

The successful interventions to recruit and retain ICT students found by our search process were organized into three categories that related to changes in computing pedagogy. One main impetus for a change in computing pedagogy came from a need to motivate more interest in computing and reduce the cognitive load for novice students learning computing for the first time. The three categories are illustrated in Figure 1 and can be briefly summarized as

- Visual programming environments to introduce novice students to computer programming
- Inquiry learning activities to engage students in computing
- Integration of interdisciplinary knowledge with computational thinking to attract students from diverse disciplines

These categories were derived from the interventions describing positive effects on the recruitment and retention of ICT students. The impact of organized day events as a recruitment intervention seemed to suggest ambiguous benefits and was excluded as a possible category. The single article listed under the social networking subsection did not share enough common features with the other articles to justify its inclusion as a separate category. The teacher professional development subsection describes auxiliary initiatives that support the main interventions and therefore was not chosen as a separate category. All the remaining subsections discuss interventions that can be organized within one of the three proposed categories.

1) Visual Programming Environments

Teaching introductory programming with a VPE appeared in both recruitment interventions with secondary school students and retention interventions with university students. The visual programming approach is in contrast to the traditional syntax-based approach. Conventional programming requires students to type syntax-dependent statements into a text editor. After typing in lines of statements to construct a complete program the program is executed and the generated results usually displayed as numbers and characters. Interacting with alphanumeric characters for both input and output has tended to encourage computing teachers to illustrate programming concepts around numerical calculation. Although appealing to students with strong abilities in mathematics this approach may not effectively introduce computational thinking to a broader audience. In fact, the core of computing resides in constructing an algorithm to solve a problem. Students without a strong mathematical background require practice designing a logically connected algorithm rather than practice writing programs to solve mathematical puzzles.

Visual programming environments create an alternative context to learn computer programming. They allow a novice programmer to interact graphically to input programming statements and generate output that is visual in nature. For example, in the Alice VPE students programmed the movement of objects in a 3-D virtual world and created animated stories. The storytelling aspect of the Alice VPE has also shown positive results in motivating middle school girls to learn computer programming [31]. The designers of the Scratch VPE recognized that conventional programming was too focused on complicated syntax, contextualized very strongly in mathematics, and lacked accessible feedback to correct programming mistakes [32]. The visual design of Scratch avoids these problems by using a drag-and-drop graphical interface to enforce proper syntax, a visual work area to generate multimedia results rather than only alphanumeric characters, and immediate feedback via multimedia output.

By appealing to computer graphic visualizations the VPEs connect computer programming to a familiar and exciting application of computing technology used extensively by the entertainment industry. VPEs demonstrate that programming can be taught in the context of creating visual animations, stories, and games. This approach can help prepare students in computational thinking who at first may not have a strong ability in mathematics. Yadin (2013) [33] reported that the use of a visual programming environment to support teaching an introductory computer programming class helped decrease the percentage of failing students from 43.1% to 9.8% two years later.

2) Inquiry-Learning Activities

The second approach to computing pedagogy demonstrated by the interventions to be successful was the use of inquiry-based activities to engage students directly in computing. These hands-on activities provided an opportunity for students to personally experience a discovery process in the context of a computing related task. The inquiry learning approach has been shown to be more effective than direct instruction [34, 35]. An important feature of inquiry teaching is to maximize the amount of self-directed knowledge a learner constructs on his or her own. This often entails practical experimentation and developing an intuitive familiarity with a problem before learning abstract theoretical concepts. Papert (1980) [36] offered a constructivist view of computing in order to promote computers as important instruments for learning and creativity.

Robot building was a popular example of inquiry learning found in the reviewed interventions. During a robotics activity students usually wrote simple software code to control an actual physical robot. They could immediately observe the effects of a software program by watching the robot’s behaviour. The robotics activities can help teach several inquiry skills including hypothesis generation, controlling experiment variables, data interpretation, and critical thinking. Robot building allows students to immediately begin controlling a robot with simple programming instructions, e.g. move forward, rotate 180 degrees. Programming concepts are introduced naturally in the context of experimenting with new robot functionalities, e.g. a decision-making programming structure arises when a student has to handle data from a robot’s sensors. Abstract knowledge follows from solving particular problems in practice and then extracting a general pattern or problem-solving strategy. Rusk, Resnick, & Berg (2008) [37] point out that the elements of robotics can be used to build diverse types of programmable machines (e.g. security alarms, coloured light effects, mechanical puppets, controllable musical instrument, etc.) that can appeal to greater range of students than the typical robotic car or robotic humanoid.

3) Interdisciplinary Integration

The third pedagogical approach shown by the interventions to be effective was the integration of interdisciplinary knowledge with computer science. Instead of presenting computing as a narrow technical discipline some of the interventions attempted to connect computation thinking to a wider range of possibilities. It has been argued that computing should involve creative opportunities to explore, experiment, and design [38]. A broader view of computing has the potential to provide interesting and relevant topics to contextualize learning for students.

For instance, courses in compute game development were introduced by the interventions to broaden interest in computer science. The gaming classes attracted students majoring in interactive media, animation, and fine arts. In general, Sung (2009) [39] contends that computer games can integrate with existing computer science classes to present abstract computing concepts within a context that motivates student engagement and enthusiasm. He claims that such integration “is a promising strategy for recruiting and retaining potential students” (Sung, 2009, p. 76 [39]). Protopsaltis, Pannese, Pappa, & Hetzner (2011) [40] also argue that games can motivate learning at both the emotional and cognitive levels, thereby offering “a powerful tool in the effort against de-motivation and dropouts” (Protopsaltis et al., 2011, p. 2 [40]).

Another interdisciplinary intervention connected introductory programming to biology topics—offering life science students an incentive to explore computing in more depth. The boundary between computer science and other disciplines has become less and less definitive due to the ubiquitous proliferation of computing technology. By offering ICT students opportunities to integrate computation with cross-disciplinary subjects the interventions stress the generality of computing in society and highlight the numerous possibilities afforded by ICT skills.

ICT also has natural interconnections with other engineering domains like embedded systems, robotics, smart systems or mechatronics. As mentioned before, robotics can attract students to ICT studies. This can be especially true for students who like to see their programming output not only on the computer screen but in the real world, e.g. on smart devices. Programming real systems gives additional motivation for many students and therefore the natural connection between ICT and mechatronics can benefit the ICT curricula. Kurkovsky (2013) [41] introduced robotics-related material into a mobile computing class and reported that students generally viewed the integration positively. At the introductory level the Lego MindStorm platform and recent popular platforms such as Arduino, Robotic HomeLab and even Raspberry Pi offer good possibilities for integrating ICT knowledge with interdisciplinary applications. Sell, Seiler, and Ptasik (2012) [42] used the

Robotic HomeLab kit to blend aspects of computer programming with the electromechanical control of robotic systems for a university class, and argue for more opportunities to integrate computing, electronics, and mechanical engineering.

B. Limitations of Studying ICT Interventions

A final but rather significant comment about the three approaches to computing pedagogy suggested by the interventions as advantageous for the recruitment and retention of ICT students' concerns the methodology used to isolate these approaches. As previously mentioned, the research articles describing interventions did not conduct rigorous statistical comparisons between treatment and control groups. A number of factors can affect student decisions, attitudes, and career choices in ICT. Without isolating factors with methodologically rigorous testing it is not possible to make reliable and definitive conclusions. The shortcomings of existing research on the topic of interventions to recruit and retain ICT students therefore allows only for tentative and potential solutions. Moreover, factors that may be influential (e.g. role models, cultural attitudes) but require interventions to last over a longer period of time to isolate are possibly overlooked because practicality favours short term interventions. Finally, the focus on computing pedagogy is in some ways not surprising since most of the articles originated from researchers at university computer science departments. Pedagogy is a factor that educators have direct control over and is therefore susceptible to changes in practice. Nevertheless, for the moment pedagogy may be the most important factor that ICT educators can change to influence the recruitment and retention of ICT students.

V. CONCLUSION

In this review we examined the research literature on interventions to recruit and retain ICT students. We identified important changes in computing pedagogy that characterized successful interventions and organized them into three categories. The first category–visual programming environment–offers a non-mathematical context to teach novice students introductory programming and avoids many of the learning difficulties associated with a syntax-dependent programming language. The second category–inquiry learning activity–provides hands-on discovery experiences that can motivate interest in computing through active engagement and personalization. Finally, the third category–interdisciplinary relevance–integrates computational thinking with diverse disciplines to encourage students to learn computing in parallel with another subject, e.g. arts & media subjects such as video game development or science subjects such as biology.

Industry demand for qualified ICT professionals requires educators to find new ways of preparing larger numbers of students for careers in ICT. This review shows that current interventions have focused on changes to computing pedagogy. This study can be applied by educators looking for promising teaching strategies to increase enrolment or reduce attrition of students in ICT-related courses and curricula.

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