WIP: An Elective Subject on Education in a Bachelor's Degree in Computing

David Lopez
Barcelona School of Informatics
Universitat Politècnica de Catalunya
Barcelona, Spain
david.lopez@upc.edu 0000-0002-7993-3799

Raúl López Sánchez
Institute of Educational Sciences
Universitat Politècnica de Catalunya
Barcelona, Spain
raul.lopez.sanchez@upc.edu 0000-0002-5175-4596

***Abstract*— This work-in-progress innovative practice paper describes an elective education subject offered in a Bachelor's Degree in Computing, introduced for the first time in the spring semester of 2024. The course has been integrated into the curriculum in response to the increasing opportunities in the education sector for our graduates. The paper outlines the instructional design of the course, and presents initial findings from the experience along with lessons learned.**

Keywords—STEM education, Education as a career path for engineers, Computing pedagogy

I. Introduction

This work-in-progress innovative practice paper details the development and implementation of a novel elective course in education currently in progress within the realm of Bachelor's Degree in Computing curriculum at the Barcelona School of Informatics of the Universitat Politècnica de Catalunya (UPC), Spain.

Education has emerged as a crucial career trajectory for graduates in the field of Computing and it is gaining increasing significance [3]. Professional development through training is imperative for professionals seeking to remain abreast of contemporary methodologies (such as Scrum and DevOps), cutting-edge technologies (like IoT and 5G/6G), diverse products (like LLMs and Dockers), and essential knowledge domains (e.g. cybersecurity and Big Data). Moreover, there exists a burgeoning demand within primary and secondary education sectors, necessitating the creation of educational resources, assistance in content design, and the provision of teacher training programs. Additionally, efforts to bridge the digital divide and enhance digital literacy across the populace underscore the necessity for training courses and educational materials aimed at imparting essential digital skills. Addressing these challenges requires individuals who possess proficiency in computing alongside a comprehension of the educational fundamentals pertaining to technology and computing. A recent report conducted within our country concerning the requisites in computing education on a national scale [11] advocated for the integration of a Computing Didactics subject into undergraduate programs within Computing Degrees.

Our school has introduced an elective subject titled "Education, Engineering, and Technology" (EET) into the Bachelor's Degree in Computing curriculum. This course was first offered in the spring semester of 2024 and commenced in February 2024 with the first cohort comprising 19 students. EET is designed to explore the foundational principles of education pertinent to computing graduates to pursue careers in the educational sector. While fundamental educational theories are examined, the emphasis is placed on learning methodologies specific to engineering and technology, with a particular focus on computing.

The EET curriculum encompasses a set of teaching methodologies, including but not limited to master classes, Project Based Learning, the flipped classroom approach, and gamification. These methodologies are explored across various media platforms, such as traditional blackboard presentations, slide-based lectures, video tutorials, podcasts, wikis, and web pages. Educational activities are designed to accommodate diverse learning modes, including face-to-face and online formats, synchronous and asynchronous activities, with or without the integration of technology. Throughout the course, students are exposed to and encouraged to practice these methodologies, with assessment conducted primarily through project-based evaluations.

Upon completion of the course, students are expected to possess the capability to effectively communicate computing concepts to diverse audiences within various educational environments. This paper aims to provide an overview of the course content, methodologies employed, instructional materials utilized, and the evaluation system implemented. Preliminary findings from the course are anticipated to be presented at the upcoming congress in October.

II. Related Work

The education of computing has been a subject of study since its inception, primarily focusing on programming learning, for example, with the development of the LOGO language [17] in the 1980s. In designing the EET subject, we conducted a literature search for similar courses, finding few analogous experiences. Many references were oriented towards explaining computing concepts [7][20], particularly programming, to students at both pre-university [10][18][22] and university levels [2][5][13][19], or advancing research in computing education [8][14], but they did not discuss the design principles of a course like EET. Most of the courses found on computer science education within the university curriculum were geared towards Teachers Assistants and PhD students [15][16].

In November 2023, the study by Cunningham, Parker, and Zhang [4] was published, analyzing 44 university-level computer science education courses, primarily in the United

States (82%). Out of these 44 courses, 24 were geared towards teachers, 18 towards research, and 2 towards tool design. The authors examined the content of 39 of these courses, identifying 550 topics categorized into 7 themes, namely: 1) Instructional Methods, 2) Classroom and Teacher Practices, 3) Theories of Thinking and Learning, 4) Diversity, Equity, and Inclusion, 5) Computing Education Research, 6) Technological Applications, and 7) Computing Content. In this work, the authors asserted "Only a small number of courses about CSEd have been described so far in the literature, and we do not find any work that contrasts different types of CSEd courses or summarizes the metadata, topics and learning objectives of such courses."

III. The EET subject history and design

Spain has historically maintained an economic system centered on services, which has endured the repercussions of recent economic crisis. Presently, there is a concerted effort to transition towards a knowledge-based model, with aspirations to position Spain as a technological hub. In pursuit of this goal, the Government has devised an agenda known as Digital Spain 2025, entailing a projected investment of 70 billion euros. However, there exists a disparity between the quantity of qualified experts in STEM disciplines and market demands, thereby exerting pressure on the Spanish educational system to cultivate professionals equipped with technological competencies, particularly in computing. In response to this imperative, the Scientific Computing Society of Spain and the Spanish Conference of Directors and Deans of Computing Engineering commissioned a panel of experts to produce a report on the status of computing education in Spain, along with a series of strategic recommendations aimed at improving the situation. The report was published in January 2023 [21] and was subsequently presented at the FIE congress held that same year [11].

In accordance with the report's recommendation to introduce an elective subject on computing didactics within undergraduate studies, the Dean of our institution advocated for the creation of such a course, slated to commence in the spring semester of the 2023-24 academic year. The initial phase involved entrusting the design and instruction of the course to two lecturers (the authors of this paper). The first author holds a PhD in computing and boasts over three decades of experience as a university professor in computing, in addition to more than two decades as a researcher in engineering education. The second author, a computing engineer, possesses a master's degree in technology education and currently combines roles as a technology educator at a high school (for 22 years) and a lecturer in the master's program in technology education at our university, also with experience in business training in the field of computing.

The initial step involved collaborative brainstorming sessions among the two instructors and the school dean to devise the instructional framework for the course. The outcome of this deliberative process was presented in the form of a poster at Jenui [12], the foremost Spanish conference on university-level computing education, with the aim of soliciting feedback from the academic community.

With the feedback received and after a process of searching for similar experiences, a design was carried out following six phases: 1) Detect the characteristics of the students who could enroll in the course, 2) Define the learning objectives, 3) Formulation of curriculum content, 4) Selection of pedagogical methodologies, 5) Choose or create the instructional materials and 6) Define the assessment framework. These points are detailed below.

IV. The EET subject design

A. *Students' profile*

Students eligible to enroll in the course are in their third or fourth year of the Bachelor's Degree in Computing, as they cannot enroll elective subjects during the first two years. Upon completing their degree, these students are not qualified to work as teachers in primary and secondary education, since in Spain education is a regulated profession, requiring specific qualifications. For early childhood and primary education, a Degree in Education is necessary. For secondary education, completion of a Master's Degree in pedagogical and didactic training, consisting of 60 ECTS credits, is required. This Master's Degree includes a common generic module (20%) and a specific module with teaching specialties, such as language teaching or mathematics, being two specialties computing and technology. To pursue this Master's Degree, students must demonstrate proficiency in the competencies related to their chosen specialization.

While some students may consider pursuing these studies in the future, it is not the primary objective of the course. Similarly, the course does not aim to train Teacher Assistants, as this role is nonexistent in Spanish universities, nor does it intend to prepare students for computing education research, as a master's degree is required to enroll in a doctoral program. Consequently, upon completion of the course, students will be equipped to work as educators in non-regulated educational settings, teaching primary or secondary school teachers, or as developers of curricula or learning tools focused on technology or computing.

Regarding the knowledge possessed by students at the outset of the course, they have a strong understanding of computing but no background in education. The TPACK model [9] distinguishes between content knowledge, pedagogical knowledge, and technological knowledge. These forms of knowledge can be delineated individually, but they also intersect (Figure 1).

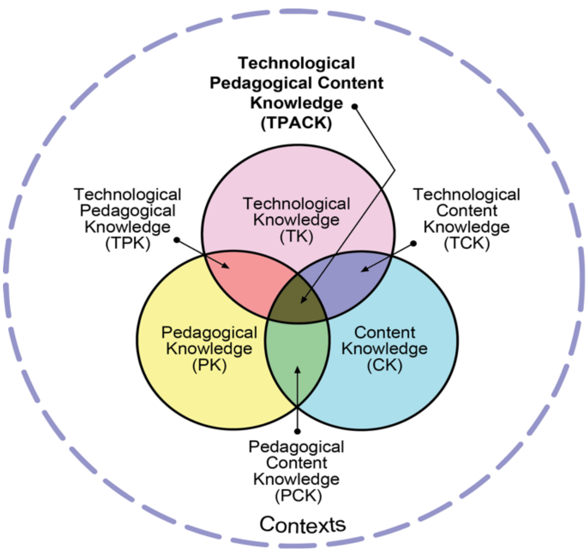

Fig. 1. The TPACK model (Koehler and Mishra, 2009). Reproduced by permission of the publisher, © 2012 by tpack.org

Content knowledge (CK) refers to the teacher's comprehension of the subject matter intended for instruction. This knowledge must align with the standards acknowledged by subject matter experts and varies depending on the educational level and field of study. It encompasses facts, concepts, theories, frameworks, methodologies for discerning evidence and truth, and operational procedures. We assume that our students do not need to delve deeper into this knowledge.

Technological knowledge (TK) represents the type of knowledge that undergoes the most rapid changes, particularly concerning the utilization of digital technologies. This knowledge is akin to digital competence in utilizing digital media, although other technologies are also involved. We likewise assume that our students possess proficiency in this knowledge domain.

Pedagogical knowledge (PK) refers to the comprehensive understanding that teachers possess regarding educational processes and methodologies, covering various facets including student learning and teacher instruction. This encompasses a range of elements such as understanding student learning processes, devising curriculum plans, managing classroom dynamics, employing effective instructional techniques, and implementing assessment methods. We believe that pedagogical knowledge, alongside the intersections among content, pedagogical, and technological knowledge, represents areas where our students may lack proficiency, thus underscoring the need for dedicated attention within the course.

B. Defining Learning Outcomes

The learning outcomes have been defined in accordance with the guidelines outlined in the Recommendation of the European Parliament and of the Council dated 23rd April 2008 concerning the establishment of the European Qualifications Framework for Lifelong Learning [6]. *"Learning outcomes" means statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competence.* The learning outcomes formulation should consist of a verb that describe measurable or observable actions, (e.g. "explain", "represent", "apply", "analyze", "develop", etc.) and the related object as well as an additional sentence describing the context. The subject learning outcomes were defined as follows: At the end of the course, the student will be able to 1) explain the fundamental principles of education applicable to a computing environment; 2) use various types of educational models related to computing across different educational environments; 3) articulate the possibilities, needs, and requirements associated with each type of education in the computing environment; 4) apply what they have learned in organizing, teaching, creating materials, and evaluating educational activities within the context of technology and computing; 5) adapt principles, methodologies, and educational materials related to computing for activities at any educational level; 6) analyze his/her own abilities and recognize limitations in the role of a trainer in a STEM environment, particularly in computing; and 7) design activities tailored to the needs of each group of learners in a technology and computing teaching-learning environment.

C. Content

As indicated in the related work section, we did not find any courses with similar characteristics to the one we were developing. Consequently, we compiled a list of topics to be covered from scratch based on our own expertise. The content was decided prior to the publication of the aforementioned article by Cunningham, Parker, and Zhang [4]. However, upon analyzing the findings of that research, we observed that we addressed all the themes and topics described therein, except those related to research in computing education, which is logical as this is not an objective of the course. Therefore, we can assert that the content is aligned with the findings of the aforementioned research, covering topics of Instructional Methods; Classroom and Teacher Practices; Theories of Thinking and Learning; Diversity, Equity, and Inclusion; Technological Applications; and Computing Content.

D. Methodology

The guiding principle behind the design has been to ensure that students not only acquire knowledge of various teaching methodologies but also experience them firsthand. Consequently, students have engaged in traditional lectures, flipped classrooms, active methodologies such as the Aronson puzzle, gamification, or Project-Based Learning, with some students even designing the activities themselves. Classes have been conducted both face-to-face and online, synchronously and asynchronously, with or without the use of technology. Further details on some of these activities will be provided in the "preliminary results" section later on.

E. Materials

The materials made available to students were sourced from those used in the Technology Education Master's Program offered by our university, along with a selection of papers and some materials specifically developed by the instructors. The materials were predominantly written in Spanish and Catalan, the official languages of our region, as we anticipated that students would apply their learning locally and we aimed for them to become acquainted with the language specific to computing education. Nevertheless, in the future we wish to create a trilingual dictionary of terms in Spanish, Catalan, and English.

During the course, students develop their own materials as a result of their projects. It is our intention that a portion of these materials be utilized in future editions of the subject. This will not only provide us with material tailored to the needs of future students but will also serve as examples of developed projects, thereby enhancing student motivation to produce high-quality materials.

F. Assessment

The assessment system is based on achieving objectives following the philosophy of acquiring Digital Badges, allowing students to personalize their learning experiences through a hierarchical model with different levels of mastery acquisition, which can lead students to go beyond what the course demands [1]. We have termed the system "credential acquisition," and three levels of acquisition have been defined: basic (knowledge acquisition), advanced (skills acquisition), and profound (competence acquisition). For each topic of the course (such as attention to diversity or evaluation methodologies), what students must do to acquire each of the three levels is defined, allowing them to choose which topics are most interesting to them to explore in greater depth. For example, in the case of the flipped classroom methodology, it is defined the necessary task for obtaining the basic credential (reading a paper describing the characteristics of the flipped classroom, educational theories on which it is based, and common mistakes, participating in a discussion on this paper), for the advanced level (participating in a flipped classroom, conducting a critique of its design according to the principles learned), and for the profound level (designing an activity consisting of a flipped classroom and leading it in the classroom). To pass the course, all students must obtain all the basic credentials, at least four advanced credentials, and one profound credential. Each student has chosen a task to perform related to a profound credential and according to their own interests. Additionally, they are assigned to analyze the work of four of their peers to obtain advanced credentials. From this point, they can choose other advanced or profound activities to increase their final qualification.

We would have liked to offer a digital badge for the work done, but our university is studying the system to offer these digital certificates, so we have only used the philosophy behind the idea, hoping that in future editions we can offer these Digital Badges.

V. Preliminary Results

The subject was offered in the spring semester of 2024. Our students enroll twice a year, in July for courses in the fall semester and in February for courses in the spring semester. Elective subjects may define the maximum number of students who can enroll. In our case, it was limited to 20 students, which is customary for the first edition of an experimental course. Students enroll based on their cumulative grade point average, with the highest-performing students given priority. The 20 available slots were filled when only one-third of the students had enrolled, indicating that the students who took the EET subject were among the top third of the student body in terms of academic performance. During the first week one student withdrew from the course leaving the experimental group comprised of 19 students.

At the time of writing this paper, there are four weeks remaining until the conclusion of the course, but some preliminary results can be discussed regarding attendance, student motivation, engagement, and the quality of submitted work. Attendance in the course has been nearly perfect for almost all classes, with only occasional absences of one or two students. In all cases of absence, students contacted us to apologize, explaining their reasons and inquiring about tasks to compensate for their absence, although such justification was not required. Considering that the average class attendance in our school is around 60%, we interpret this as indicative of significant motivation and commitment to the subject. Students selected their projects for deep accreditation based on their interests, and each student has been assigned to analyze four projects from their peers to obtain advanced accreditation, as well as to provide peer feedback. The submitted works thus far have been of sufficient quality for all students to pass the course. The remaining projects before the course concludes will serve to boost the grades of the most engaged students. Subjectively, instructors have frequently remarked that this group displays an unprecedented level of interest and dedication, with highly participative class discussions.

Two special tasks will provide us with additional insights. Firstly, a class was dedicated to discussing the organization of the curriculum they are currently studying. This exercise allows them to examine a curriculum that everyone is familiar with and discuss it from various perspectives such as motivation, teaching methodologies, instructional design, etc. It has been a very interesting exercise, recorded with students' permission, and we are awaiting transcription and analysis to draw conclusions. The second exercise has yet to take place, but we intend to propose it as a formal letter from each student to the instructors, explaining their expectations of the subject when they enrolled, what they believe they have learned about education, whether it has influenced their motivation and perception of their strengths and weaknesses as students, as well as their own vision of the future of computing education. We hope that the qualitative analysis of the data from these two activities will allow us to improve both the design of the course and the rest of the degree program.

VI. Conclusions

This paper has presented the implementation of an educational subject within a Bachelor's Degree program in Computing, currently in development. The design is discussed, and initial findings are presented.

The rapid development of computing necessitates significant efforts in education. It includes spanning enhancements in content and learning methodologies in primary and secondary education, the reduction of the digital divide in the general population, and training in products or new technologies for professionals in the computing field and other fields. Education as a field of professional development is increasingly important among computing graduates, thus necessitating the inclusion of subjects oriented toward the teaching-learning process within the computing degree curriculum.

As a future work, we aim to analyze the impact on motivation for a teaching career and the perception of this professional trajectory among students enrolled in the course. Additionally, we plan to redesign the course based on feedback received from both students and the broader community with whom we have shared our experience.

Acknowledgment

The authors express their gratitude to Josep Fernandez-Ruzafa, Dean of the Barcelona School of Informatics, for spearheading the initiative and providing unwavering support. This work has been funded by the Departament de Recerca i Universitats de la Generalitat de Catalunya – 2021 SGR 01412

References

[1] H.A. Alamri, S. Watson, and W. Watson. "Learning technology models that support personalization within blended learning environments in higher education." *TechTrends* 65, no. 1 (2021): 62-78. https://doi.org/10.1007/s11528-020-00530-3

[2] B. A. Becker and T. Fitzpatrick. "What Do CS1 Syllabi Reveal About Our Expectations of Introductory Programming Students?". In Proc. of SIGCSE '19, 1011–1017. https://doi.org/10.1145/3287324.3287485

[3] CSEdGrad.org. 2021. "CSEdGrad: Exploring Pathways of Future CSEd Researchers". https://www.csedgrad.org/

[4] K. Cunningham, M. C. Parker, and J. Zhang. "The Landscape of Computer Science Education Courses: A Syllabi Analysis." In *23rd Koli Calling*, Int'l Conf. on Computing Educastion Research pp. 1-11. 2023. https://doi.org/10.1145/3631802.3631831

[5] du Boulay, B., O'Shea, T. & Monk, J. (1981) "The black box inside the glass box: Presenting computing concepts to novices", Int'l Journal of Man-Machine Studies, 14(3):237-249, https://doi.org/10.1016/S0020-7373(81)80056-9

[6] European Parliament, Council of the European Union. “Recommendation of the European Parliament and of the Council of 23 April 2008 on the establishment of the European Qualifications Framework for lifelong learning”. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32008H0506%2801%29

[7] T. Götschi, I. Sanders, and V. Galpin. “Mental models of recursion”. En Proceedings of the 34th SIGCSE Technical Symposium on Computer Science Education (SIGCSE 2003), pp. 346-350 https://doi.org/10.1145/611892.612004.

[8] S. Heckman, J. C. Carver, M. Sherriff, and A. Al-zubidy. “A Systematic Literature Review of Empiricism and Norms of Reporting in Computing Education Research Literature”. ACM Trans. Comput. Educ. 22, 1, Article 3 (oct 2021). https://doi.org/10.1145/3470652

[9] M. Koehler, and P. Mishra. "What is technological pedagogical content knowledge (TPACK)?." *Contemporary issues in technology and teacher education* 9, no. 1 (2009): 60-70. https://www.learntechlib.org/primary/p/29544/

[10] J. Kim, A. Leftwich, and D. Castner. “Beyond teaching computational thinking: Exploring kindergarten teachers’ computational thinking and computer science curriculum design considerations”. *Educ Inf Technol* (2024). https://doi.org/10.1007/s10639-023-12406-z

[11] D. Lopez, F. Llorens-Largo, M.M. Marqués-Andrés and J.A. Velázquez-Iturbide. “Proposals for the promotion of computing in K-12 studies in Spain”. Frontiers in Education Conference. FIE 2023: College Station, TX, USA, October 18-21, 2023. https://doi.org/10.1109/FIE58773.2023.10343195

[12] R. López-Sánchez, D. López, and J. Fernandez-Ruzafa. “Reflexiones sobre el diseño de una asignatura de educación en el grado de ingeniería informática. Jenui 2023, Granada, july 2023 (in Spanish) https://aenui.org/actas/pdf/JENUI_2023_054.pdf

[13] McCracken, M., Kolikant, Y.B.-D., Almstrum, V., Laxer, C., Diaz, D., Thomas, L., Guzdial, M., Utting, I., Hagan, D. & Wilusz, T. (2001) "A multinational, multi-institutional study of assessment of programming skills of first-year CS students", ACM SIGCSE Bulletin, 33(4):125-140, Dic. 2001. https://doi.org/10.1145/572133.572137

[14] M. McGill et al. “Conducting Sound, Equity-Enabling Computing Education Research”. In Proceedings of ITiCSE-WGR 2023 (30-56). https://doi.org/10.1145/3623762.3633495

[15] M. Minnes. “Designing TA Training for Computer Science Graduate Students: Remote and Self-Paced Options for A Supported Introduction to Re- flective Teaching.” In SIGCSE 2022. https://doi.org/10.1145/3478431.3499342

[16] D. Mirza, P. T. Conrad, C. Lloyd, Z. Matni, and A. Gatin. “Undergraduate Teaching Assistants in Computer Science: A Systematic Literature Review”. In Proc. of the 2019 ACM Conference on International Computing Education Research (Toronto ON, Canada) (ICER ’19). https://doi.org/10.1145/3291279.3339422

[17] S. Papert. 1980. “Mindstorms: Children, Computers, and Powerful Ideas”. Basic Books, Inc., USA.

[18] D. Parsons, and P. Haden. “Parsons’ programming puzzles: A fun and effective learning tool for first programming courses”. En Proc. of the 8th Australasian Conf. on Computing in Education (ACE 2006), pp. 157-163 https://dl.acm.org/doi/abs/10.5555/1151869.1151890

[19] A-K. Peters.”Students’ Experience of Participation in a Discipline—A Longitudinal Study of Computer Science and IT Engineering Students”. ACM Transactions on Computing Education. 19(1):1-28 2019. https://doi.org/10.1145/3230011

[20] E. Soloway. "Cognitive strategies and looping constructs: An empirical study", Communications of the ACM, 26(11):853–860, Nov. 1983. https://dl.acm.org/doi/pdf/10.1145/182.358436

[21] J.A. Velázquez-Iturbide, F. Llorens-Largo, D. López, and M.M. Marqués-Andrés. “Informe CODDII/SCIE sobre formación del profesorado y didáctica de la informática en etapas preuniversitarias” (In Spanish). URL: https://rua.ua.es/dspace/handle/10045/131535

[22] B. Wong. “‘I’m good, but not that good’: digitally-skilled young people’s identity in computing”, Computer Science Education, 26(4):299-317. 2017 https://doi.org/10.1080/08993408.2017.1292604