Empowering Future Engineers: Unveiling Personalized Flipped Classrooms in Basic Programming Education

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Keywords: Computer Engineering Education, Flipped Classroom, Personalized Learning, Programming.

Abstract: In the evolving educational landscape of the 21st century, innovative pedagogical methods like the Flipped Classroom (FC) and Personalized Learning (PL) have increased renown. The FC methodology revolutionizes traditional teaching by moving initial concept exposure outside the classroom, allowing in-class time for interactive and practical activities. This approach increases a dynamic learning environment, enhancing critical thinking, problem-solving, and collaboration skills. Successful FC implementation involves comprehensive educational experiences utilizing digital resources and active classroom interactions. PL adapts teaching to individual student needs, recognizing diverse learning speeds and cognitive styles. By leveraging technology, PL provides customized educational experiences that increase learner autonomy and motivation, leading to deeper understanding and engagement. A case study on teaching C programming using a Personalized Flipped Classroom (PFC) approach illustrates the practical application of these methodologies. The course design includes structured planning, multimedia resources, and continuous evaluation, promoting effective learning. Students engage with instructional videos and practical exercises, promoting autonomy and active participation. The course covers fundamental programming concepts, with a thematic progression that balances foundational understanding and advanced topics. Despite challenges like increased workload and digital competency gaps, the PFC approach demonstrates significant potential in enhancing student performance and skill development.

1 INTRODUCTION

In the changing educational landscape of the 21st century, the constant search for innovative pedagogical methods that maximize student learning and engagement has led to the evolution of disruptive approaches. One of the educational paradigms that has gained prominence is the Flipped Classroom (FC), a methodology that challenges traditional conventions by shifting the dynamic between classroom instruction and time spent on independent work (Abeysekera and Dawson, 2015).

FC represents a revolutionary methodology on conventional teaching by moving the initial exposure to concepts outside the classroom. Instead of receiving crucial information during class time, students are immersed in the material in advance, using a variety of multimedia resources and interactive tools to acquire knowledge prior to the in-person session with the educator. This strategic variation allows in-class time to be devoted to activities that are more interactive, collaborative and focused on the practical application of learned concepts (DeLozier and Rhodes, 2017).

The essence of FC lies in the creation of a dynamic, participatory learning environment. The theory behind this approach is based on the premise that learners can benefit significantly from having a first contact with information in a self-directed environment (Yildirim and Kiray, 2016). This approach not only targets knowledge acquisition, but also focuses on the development of critical thinking, problem-solving and collaboration skills, crucial elements in the holistic formation of students.

Successful implementation of FC goes beyond simply providing pre-study material. It is about designing a comprehensive educational experience that takes full advantage of digital resources, digital learning platforms and classroom interactions (Sointu et al., 2023). Educators play a key role in creating engaging resources and facilitating meaningful discussions that make the most of class time.

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Aldalur, I., Markiegi, U. and Sagarna, X.
Empowering Future Engineers: Unveiling Personalized Flipped Classrooms in Basic Programming Education.
DOI: 10.5220/0013258200003932
In *Proceedings of the 17th International Conference on Computer Supported Education (CSEDU 2025) - Volume 2*, pages 678-685
ISBN: 978-989-758-746-7; ISSN: 2184-5026

As FC becomes ingrained in educational practices, reports of substantial benefits emerge in a variety of educational contexts (Akçayır and Akçayır, 2018). Students report higher levels of engagement, deeper understanding of concepts, and greater autonomy in their learning process. In addition, educators find opportunities for instructional differentiation, personalized feedback, and greater connection with students. Among the reasons for using FC are that it improves student engagement and motivation, enables flexible learning, or enhances student autonomy (Akçayır and Akçayır, 2018).

However, the adoption of FC is not without its challenges. From initial resistance to the need for equitable access to technological resources. In addition, it is noted that some students show up to classes with limited preparation. Likewise, the adoption of FC leads to an increased workload for both lecturers and students, and there is evidence of a lack of digital competencies among both lecturers and students (Ormiston et al., 2022). However, overcoming these challenges can lead to significant rewards in terms of improved student performance and the development of essential skills.

On the other hand, Personalized Learning (PL) represents a fundamental evolution in education. Personalization refers to "a lecturer's relationships with students and their families and the use of multiple instructional modes to scaffold each student's learning and enhance the student's motivation to learn and metacognitive, social, and emotional competencies to foster self-direction and achieve mastery of knowledge and skills" (Redding, 2013). PL is oriented towards the adaptation of teaching to the individual needs of each student. This approach revolutionizes the educational paradigm by recognizing and addressing the different learning speeds, cognitive styles and preferences of students. By focusing on personalization, learning becomes more flexible, allowing educators to design educational experiences that are tailored to each student's specific strengths and challenges. Technology plays a crucial role in facilitating this personalization, providing interactive tools, adaptive assessments, and multimedia resources that align with individual learning goals (Shemshack and Spector, 2020). This approach not only boosts learner autonomy and motivation, but also raises deeper and more enduring understanding by directly addressing each individual's unique needs. Ultimately, PL not only redefines the way education is delivered, but also stands as a catalyst for forming a community of autonomous and engaged learners.

In this context, this paper presents the Personalized Flipped Classroom (PFC) experience for the 2 degrees in energy and eco technology of our university in the 1st course for the subject of basic programming. The reception of this experience has been qualitatively measured, answering the following research questions:

- RQ1: How do students perceive the overall effectiveness of the PFC modality compared to the traditional teaching model?
- RQ2: How do students' learning preferences influence the acceptance and usefulness of audiovisual resources in PFC?
- RQ3: How do students perceive the distribution of time between homework and classroom activities in the PFC model?
- RQ4: How do students feel about the flexibility and autonomy provided by self-paced learning in PFC?
- RQ5: How do students perceive the effectiveness of consolidating and applying knowledge in the PFC model?

2 RELATED WORK

In recent years, PFC has emerged as a promising methodology for improving student learning. The benefits of PFC include tailored pacing for individual student needs, allowing for pause, reflection, and review. Lecturers can utilize their expertise more effectively, providing targeted practice based on student assessments. Increased class time enables more personalized interactions, fostering relationships and understanding of students' strengths and weaknesses. Additionally, extended class periods facilitate active student engagement and explicit teaching of essential skills like critical thinking and collaboration (Sota, 2016). PFC combines elements of traditional FC, in which students watch educational videos at home, with a personalization of learning that caters for the individual needs of each student. For example, Sein et al. (Sein-Echaluce et al., 2022) developed and implemented a PFC model that consists of personalized homework at home. The model allows students to learn lessons and perform micro-activities according to their level of knowledge and readiness. The model is designed by establishing groups of students according to their level of knowledge and, in this way, personalized activities are designed for each group, which are carried out cooperatively. The results of the experience show an improvement in student performance as a result of the customized activities designed. In another study, Matsui et al. (Matsui and

Ahern, 2017) examined how and why certain tasks were performed by students in an PFC curriculum. In this curriculum, before attending class, students had the choice of watching a video in Japanese, one in English, and/or reading the textbook to learn grammar points through Google Forms. The findings show a tendency for the most successful students to choose Japanese videos and/or textbooks, while the least successful students choose English videos and/or textbooks. The findings also show the need for improvement to provide more classroom learning opportunities and effective use of class time for higher achieving students.

In other PFC cases, new technologies such as Artificial Intelligence (AI) or cell phones have been used. Huang et al. (Huang et al., 2023) applied AI-enabled personalized video recommendations to stimulate students' motivation and learning engagement during a programming course. They assigned students to control and experimental groups comprising 59 and 43 undergraduates, respectively. Students in both groups received FC instruction, but only those in the experimental group received AI-enabled personalized video recommendations. They quantitatively measured student engagement based on their learning profiles in a learning management system. The results revealed that AI-enabled personalized video recommendations could significantly improve the learning performance and engagement of students with a moderate level of motivation. Chaipidech et al. (Chaipidech and Srisawasdi, 2018) developed a prior knowledge-based PFC approach. Students were provided with a video related to a concept to explore a phenomenon and a research question. The effects of the developed approach with mobile technology on students' physics educational performance and motivation were investigated. It was found that students significantly outperformed the subject compared to other approaches, and their intrinsic scientific motivation was positive.

Taken together, these studies suggest that PFC can be an effective tool for improving student learning. PFC has the potential to personalize learning to address the individual needs of each student, which can lead to greater engagement and performance.

3 CASE STUDY

In this case study, we explore the implementation of a PFC experience-centered approach to teaching C programming. This pedagogical approach is characterized by the inversion of traditional learning dynamics, introducing fundamental concepts through structured planning and making strategic use of multimedia resources with the objective of enhancing students' comprehension and retention of information. The methodology is broken down into several stages and focuses intensively on active interaction in the classroom, as well as on continuous evaluation, thus creating an environment conducive to effective and meaningful learning.

At the beginning of the course, students are provided with a detailed plan that not only outlines the topics to be addressed each week, but also includes practical exercises and instructional videos for review. This initial phase also establishes the key dates for the three exams scheduled throughout the course, thus providing a clear and organized structure for the academic development of the participants.

The course syllabus includes the following topics:

- Introduction to programming.
- Basic concepts, including conditional structures (if), loops (for, while, do-while), and switch.
- Functions.
- Arrays.
- Strings.

This thematic progression is distributed over several weeks, allocating 5 weeks to the basic concepts and 9 weeks to explore in detail the rest of the more advanced topics (3 weeks for each topic). For the development of the methodology, 46 videos grouped into 5 topics have been developed with an average duration of 4:51 minutes per video. This approach seeks to establish an optimal balance between the understanding of the fundamentals and the progressive immersion in more complex concepts.

The teaching methodology of the course is organized in blocks of 2 weeks per subject. During the first week, students are immersed in watching videos, while in the second week they engage in hands-on practice. This cycle is repeated periodically, as each week kicks off a new topic, and the practice phases of the current topic overlap with the viewing of videos from the next topic. On the first day of class, all students complete an in-class test that assesses the most basic concepts. Depending on the results, a detailed explanation is provided to ensure understanding or progress is made considering that students have assimilated the concepts through the videos.

During the course of the classes, students are actively involved in practical exercises, and each week they are assigned a series of recommended exercises. These exercises are designed for students to approach at their own pace, giving them the flexibility to complete them according to their preferences and pace. Those who are unable to complete the assignments in the classroom take responsibility for completing them at home, thus promoting autonomy in learning. Lecturers remain available to answer questions and clarify doubts both during and outside of class. In addition, a collaborative environment is fostered where general concerns are addressed for the benefit of the entire class. It is important to note that, in order to ensure a solid understanding, students are strongly encouraged to complete all the proposed exercises, as lecturers believe this will ensure a sufficient level to pass the next exam.

The submission of assignments is done through the Moodle platform, allowing students to complete and submit their exercises until midnight on Sunday. In addition, a Quizizz quiz with more complex concepts is provided at the beginning of the week and must also be completed within the same time frame. To complete the quiz, the student has an extended period of time. This approach not only reinforces student responsibility in meeting defined deadlines, but also identifies general conceptual errors to be addressed in the following week.

The lecturers (one for the energy degree and one for the eco technology degree) carry out a selective review of the exercises submitted by the students, providing specific and personalized feedback to enhance personalized learning. In addition to the resources provided, students have access to additional videos from the beginning of each topic to assist in solving exercises. This approach offers a unique flexibility, as students have the power to decide when and if they wish to view these audiovisual resources. These videos address exercises other than those covered in class, guiding students through the formulation of solutions, the writing of pseudocode and, finally, the implementation in C code. By providing these options, students are given additional perspectives to strengthen their understanding, allowing them to customize their learning process according to their preferences and pace.

At the end of each block of topics, students take an exam. The first exam tests their mastery of each of the basic concepts. The second exam focuses on functions and arrays, while the third exam focuses on assessing knowledge of strings. Those students who do not pass have the opportunity to take a resit exam. This comprehensive methodological approach not only allows for effective teaching of C programming, but also ensures that students understand and apply the concepts in a solid way, demonstrating their knowledge through periodic exams.

This case study highlights the importance of structured planning, strategic use of multimedia resources, and implementation of continuous assessments in teaching C programming under the PFC framework. The combination of these elements not only promotes effective learning, but also empowers students to apply their knowledge practically in software development.

4 RESULTS

In this section, the students' perception of the experience is examined. It includes the survey conducted to obtain the opinion of the participants, followed by a detailed analysis of each of the research questions.

We conducted an anonymous survey addressed to the 47 students (32 in the energy degree and 15 in the eco technology degree) who participated in this initiative, in order to gather their opinions on the implementation of the PFC teaching model.

At the conclusion of the semester, before the third exam, we asked students to complete a survey for the basic programming course via Google Forms. The questions, detailed in Table 1, were formulated following the approach used by (Johnson, 2013), and responses were compiled using a 1-5 Likert scale to evaluate different aspects of the experience. The results are shown in Table 1.

The following subsections will address the research questions related to the student body based on the information collected in this survey.

4.1 RQ1: How Do Students Perceive the Overall Effectiveness of the PFC Modality Compared to the Traditional Teaching Model?

Detailed evaluation of students' perceptions of the effectiveness of the PFC modality reveals a generally positive trend toward this innovative approach. In the initial question (Q1), which inquires about the attractiveness of PFC compared to traditional teaching, an equitable distribution is observed between neutral and positive answers, highlighting the diversity of opinions. However, the median suggests a slight inclination toward the affirmative answer (A), indicating that a significant segment of students finds PFC more attractive.

A notable aspect arises when considering students' willingness to recommend PFC to their friends (Q2). Here, the results are stronger, with the majority of participants leaning toward positive responses. The median and mode, both in category A (agree), reinforce the general perception that students not only find this modality attractive, but also consider it worthy of recommendation to their peers.

Table 1: Questionnaire results (Strongly Disagree, SD; Disagree, D; Neither agree nor disagree, N; Agree, A; Strongly Agree, SA).

Questions	Frequencies					Descriptive Statistics		St. Dv.
	SD	D	N	A	SA	Median	Mode	
Q1: The Flipped Classroom is more engaging than traditional classroom instruction	2	2	17	16	10	A	N	1,01
Q2: I would recommend the Personalized Flipped Classroom to a friend	4	3	9	20	11	A	A	1,16
Q3: The Personalized Flipped Classroom gives me greater opportunities to communicate with other students	1	5	18	15	8	N	N	0,97
Q4: I like watching the lessons on video	5	12	11	15	4	N	A	1,17
Q5: I would rather have the entire class moving at the same pace in the course	4	10	11	12	10	N	A	1,26
Q6: I am spending less time working on traditional programming homework	1	9	14	10	13	N	N	1,16
Q7: Social Media (YouTube, Twitter, Facebook) are an important part in my learning	8	14	8	14	3	N	A	1,23
Q8: I regularly watch the video assignment	1	3	6	13	24	MA	MA	1,03
Q9: I like that I can take my quizzes at my own pace	1	1	13	20	12	A	A	0,9
Q10: I like taking my tests and quizzes online using Quizzizz	3	3	8	19	14	A	A	1,13
Q11: I would rather watch a video lesson than a traditional teacher lesson	3	8	13	15	8	N	A	1,15
Q12: I feel that mastery learning has improved my programming understanding	4	7	16	11	9	N	N	1,19
Q13: I like self pacing myself through the course	1	6	14	13	13	A	N	1,09
Q14: I find it easy to pace myself successfully through the course	5	13	13	13	3	N	A	1,12
Q15: The Personalized Flipped Classroom gives me more class time to practice programming	1	4	5	12	25	MA	MA	1,07
Q16: I am more motivated to learn programming in the Personalized Flipped Classroom	2	5	16	18	6	A	A	0,99
Q17: The Personalized Flipped Classroom has improved my learning of programming	4	4	9	18	12	A	A	1,2

Regarding communication opportunities (Q3), the results suggest that students have more varied opinions. While some value PFC for offering more opportunities for interaction, others do not perceive a significant change in this aspect. The median and mode in the N category (neither agree nor disagree) indicate a lack of consensus on this particular dimension.

Consistency in viewing video assignments (Q8) appears to be a strength of the PFC, as most students report regularly viewing the audiovisual materials provided. Here, the median and mode, both in the MA (strongly agree) category, highlight the effectiveness of this key component of the modality.

Motivation to learn to program with PFC (Q16) shows a clear positive bias, with the majority of students expressing an increase in their motivation. The median and mode in category A (agree) support the idea that this methodology can promote the enthusiasm and engagement among students in the area of programming.

Finally, in relation to the improvement of programming learning (Q17), the results indicate a general positive perception, although with some variability. The median and mode in category A (agree) suggest that, overall, students experience improvements in their learning thanks to PFC.

In summary, detailed evaluation of student responses highlights PFC as a generally well-received modality, with evident strengths in areas such as attractiveness, recommendation to peers, consistency in viewing audiovisual material, and motivation. However, it is crucial to recognize areas of diversity of opinion, especially in terms of communication opportunities, to guide future research and refine the implementation of the PFC.

4.2 RQ2: How Do Students' Learning Preferences Influence the Acceptance and Usefulness of Audiovisual Resources in PFC?

Evaluation of the collected data provides insight into the interaction between individual preferences and the perceived effectiveness of PFC. In particular, the answers to specific questions (Q4, Q7 and Q11) related to attitudes towards audiovisual resources shed light on learning preferences.

Question Q4, which directly addresses the preference for watching video lessons, reveals a diversity of opinions. Although response category A (agree) has a considerable number of participants, a significant proportion of responses is also observed in category D (disagree). The median and mode in the N category (neither agree nor disagree) indicate a lack of general consensus on the preference for video lessons.

In contrast to this, the importance of social networks in learning (Q7) presents a similar trend. Although some responses are distributed between categories D (disagree) and A (agree), the majority of participants lean towards not accepting social networks as an integral part of their learning process.

Finally, the preference for viewing video lessons compared to traditional lecturer-led lessons (Q11) highlights a general positive inclination towards audiovisual resources. Category A (agree) obtains substantial representation, indicating a clear preference for the video format. The median in category N suggests, however, that there is still a significant portion of students who do not present a pronounced preference.

Taken together, the lack of consensus in some areas highlights the need to adapt pedagogical strategies to accommodate diverse learning preferences and optimize the effectiveness of this innovative modality.

4.3 RQ3: How Do Students Perceive the Distribution of Time Between Homework and Classroom Activities in the PFC Model?

The evaluation of the responses provides important information about the time management in this educational approach. The answers to the specific questions (Q6 and Q15) highlight the students' perception of the balance between autonomous work and classroom activities within the context of PFC.

Regarding the time spent doing programming homework at home (Q6), the results reveal a diversity of opinions. While the D (disagree) and N (neither agree nor disagree) categories obtain significant representation, it is important to note that the mode and median are placed in the N category. Due also to high value in A (agree) and SA (strongly agree) categories, this suggests a lack of clear consensus, where some students perceive that they spend less time on programming homework at home, while others do not observe a substantial change.

In contrast, the perception of providing more classroom time to practice programming (Q15) shows a more positive trend. The overwhelming majority of participants select the A (agree) and MA (strongly agree) categories, indicating that students perceive that PFC provides them with more classroom time for programming practice. The median and mode in the MA category support this generalized perception.

Taken together, these results suggest that PFC variably impacts the distribution of time between homework and classroom activities, depending on individual student perceptions. While some may experience a reduction in time spent on homework at home, most value the opportunity to spend additional time in class, highlighting the potential flexibility and efficiency of this educational model. It is crucial to take these perceptions into account when considering the implementation and adjustment of PFC strategies to optimize the learning experience.

4.4 RQ4: How Do Students Feel About the Flexibility and Autonomy Provided by Self-Paced Learning in PFC?

The evaluation reveals different perceptions of autonomy and flexibility in this educational model. The specific results of the questions (Q5, Q9, Q13 and Q14) provide a comprehensive view of the students' response to the adaptability of the pace of learning in PFC.

The preference for moving at the same rhythm throughout the class (Q5) shows a variety of opinions, with an equal distribution between the categories D (disagree), N (neither agree nor disagree) A (agree), and MA (strongly agree). These results together with the median in the N category suggest a lack of clear consensus on the preference for a uniform pace, highlighting the diversity of opinions on this specific aspect. In addition, the result in standard deviation is the highest of all questions.

Regarding the possibility of doing questionnaires at one's own pace (Q9), the results are more definite, with the majority of participants expressing a clear preference for this flexibility. The high representation in the A (agree) and MA (strongly agree) categories, together with a median and mode in the A category, reinforces the positive perception of the autonomy provided by PFC.

The preference for following one's own pace during the course (Q13) presents a similar distribution, with a positive inclination toward autonomy. The median and mode in category A indicate that many students value the ability to adapt the pace of learning according to their individual needs.

However, the perceived ease of keeping up with the course (Q14) shows considerable variability. While some students find it easy to take the courses, others show disagreement. The median and mode in the N category (neither agree nor disagree) suggest a lack of clear consensus on this specific aspect.

In summary, the data reveal a generally positive perception of flexibility and autonomy in PFC, especially in terms of taking questionnaires at one's own pace and following one's own pace during the course. However, the diversity of opinions on even pacing and perceived ease to take the courses highlights the need to consider individual preferences when designing and implementing PFC strategies.

4.5 RQ5: How Do Students Perceive the Effectiveness of Consolidating and Applying Knowledge in the PFC Model?

The evaluation of students' perception of effectiveness in consolidating and applying knowledge in the PFC model, according to the research question, is based on the specific data collected through questions Q10 and Q12.

First, the preference for taking online quizzes using Quizizz (Q10) reveals a mostly positive response. The dominant presence of responses in the A (agree) and MA (strongly agree) categories, along with a median and mode in the A category, suggests that students find significant benefits in using online platforms to assess their understanding. This positive perception indicates that these tools can be effective in consolidating and assessing knowledge acquired in the PFC model.

Regarding the belief that PFC has improved their understanding of programming (Q12), the results indicate a mixed perception. Although a significant proportion of responses fall into the N categories (neither agree nor disagree), a good portion of students agree. The median and mode in the N category suggest a lack of clear consensus. This highlights the need to further explore the factors that influence the perception of improvement in programming understanding within the context of PFC.

In summary, the data suggest that online quizzing platforms are perceived to be effective in consolidating knowledge, as positively perceived by students. However, improved understanding of programming within PFC shows significant variability in responses, pointing to the importance of addressing specific factors that may influence this perception and optimizing the effectiveness of the modality.

5 CONCLUSIONS AND FUTURE LINES

This study presents a successful implementation of PFC in the basic programming course in energy and eco technologies. The methodology adopted involves careful planning, ranging from the delivery of a detailed plan at the beginning of the course to the strategic scheduling of exams throughout the semester. The thematic progression, focusing on fundamental and advanced C programming concepts, is distributed in a balanced manner throughout the weeks, encouraging a solid and progressive understanding. The combination of video teaching material, practical in-class exercises and the flexibility to complete assignments at home reinforce student autonomy and adaptability.

Regarding the general perception of PFC compared to the traditional teaching model, the results indicate a positive trend, with students finding this modality attractive and recommendable. In addition, the consistency in viewing the audiovisual resources provided stands out, suggesting that videos play an effective role in the learning process. The relationship between learning preferences and the acceptance of audiovisual resources in PFC reveals a diversity of opinions, highlighting the need to adapt pedagogical strategies to accommodate these individual variations. Regarding the distribution of time between work at home and classroom activities, students show diverse opinions, noting that some may perceive a reduction in the time devoted to homework at home, while most value the additional opportunity in class. On the flexibility and autonomy provided by self-paced learning in PFC, the results suggest an overall positive perception, albeit with some areas of diversity of opinion, especially in terms of preference for a uniform pace and ease to take the courses. In relation to the effectiveness in consolidating and applying knowledge in the PFC model, a positive perception is observed on the use of virtual platforms for questionnaires, while the improvement in the understanding of programming within PFC shows the need to explore specific factors that influence this perception.

In the future, a key area for future research could focus on addressing the diversity of opinions on the preference for a uniform pace of learning and the perceived ease of keeping up with the pace of the course. Further analysis to understand the reasons behind the varied responses in these categories would be beneficial. This could include exploring specific support strategies for students who prefer a more rhythm, and identifying possible barriers that might affect the perceived ease to take the courses. In addition, future research should address additional methods to optimize flexibility and autonomy in self-paced learning, seeking solutions that accommodate diverse student preferences and enhance the overall PFC experience. It is also crucial to recognize the reasons for the lack of communication opportunities among students to guide future research and refine PFC implementation.

On the other hand, we consider it important to perform a detailed cost-benefit analysis of the implementation of PFC, considering aspects such as the initial investment in technological resources, the time dedicated by lecturers and the academic results achieved. In addition, we wish to apply and evaluate PFC in other academic disciplines to determine its effectiveness and feasibility in fields other than programming, which could provide valuable information on the versatility of this approach.

ACKNOWLEDGEMENTS

This work was carried out by the Software and Systems Engineering research group of Mondragon Unibertsitatea (IT519-22), supported by the Department of Education, Universities and Research of the Basque Government.

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