An Experiential Learning Approach to Research Methods in Computer Science based on SMART Goals

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Abstract - **Research methods are perceived among the most challenging classes by students and faculty: in addition to theories, foundations, and technical aspects, they involve applying high-level critical-thinking, problem-solving, and communication skills. Simultaneously, methods courses play a significant and holistic role in contributing to the personal and professional development of students. Therefore, designing engaging and meaningful learning experiences is especially important, as research methods classes touch every dimension of student success. To this end, experiential learning (EL) approaches are among the most successful strategies adopted by faculty: in the last decade, the benefits of incorporating components, such as simulations, internships, service-learning, and fieldwork, have been demonstrated in several domains. Indeed, sharing diverse examples of applications of EL in methods classes in specific fields is beneficial for contributing to the discourse, generating new strategies, and identifying best practices.**

This paper presents the case study of a course in research methods in computer science entirely based on experiential learning. Specifically, the class was designed to match the key steps of the scholarly publishing process: throughout the semester, students generate and refine applied research projects that could eventually be published in actual academic conferences or scientific journals. The findings from three years of data demonstrate the effectiveness of the approach discussed in the paper.

Keywords - experiential learning, computer science

I. INTRODUCTION

Conducting research is a unique and fascinating activity that requires using a combination of diverse skills, from theoretical understanding to practical knowledge, and taking them to the next level to contribute to the scientific discourse. As a result, despite being particularly challenging and intellectually demanding, it is important to expose students to research from the early stages of their education. Furthermore, this becomes especially valuable in college studies both at the undergraduate and graduate levels, where being involved in research helps students develop their higher-level abilities and contribute to their success. Whether they will choose to pursue a career in higher education or outside academia, critical thinking skills and scientific approaches contribute to creating more robust foundations for their personal and professional development. To this end, methods courses are extremely valuable for introducing students to research and engaging them in broadening their theoretical horizons while simultaneously increasing their technical and practical knowledge within a particular domain and beyond the boundaries of a single discipline. While most courses focus on specific aspects of Bloom's taxonomy, research methods classes have the potential of thoroughly supporting students in mastering all the higher levels of the learning pyramid and becoming independent in their journey as a life-long learner. Moreover, in addition to enhancing their theoretical knowledge and technical skills, working with peers in collaborative research projects fosters the development of soft competencies, whereas documenting, reporting, and presenting the results of a research project help to become more proficient in communication. Given their complexity and breadth, methods modules are often perceived as among the most challenging by both teachers and learners. Indeed, among the several aspects that have to be taken into consideration in the design of the course in order to make it relevant, the most prominent is student engagement. Specifically, when the same class is offered to different majors having diverse backgrounds and objectives, teachers have to address the additional challenge of fragmentation of methodological expertise, which makes it difficult to find a common theme that fits the interest of all students and to identify meaningful projects that help learners understand how to apply the contents learned in the class to their fields while keeping them engaged[1]. As outlined by several authors, this is particularly true for research methods courses in the field computer science[1]: on the one hand, models and theories can easily be applied to other domains; on the other hand, a large degree of interdisciplinarity, transferability, and meta-cognitive knowledge requires more accurate course design and planning in order to provide students with experiences that are not theoretically superficial and technically overwhelming, or vice versa. Previous literature highlighted the value of incorporating experiential learning (EL) [2] in methods courses and demonstrated their effectiveness in producing tangible outcomes that motivate students in developing skills that are transferrable to other domains [3]. Nevertheless, due to numerous intrinsic challenges, most courses are based on simulated projects only. Although they can be a great learning environment for lower-level classes, they are perceived by more mature students as lacking practicality.

II. RELATED WORK

Case studies and simulations are among the most widespread methods for introducing experiential learning in the classroom. Findings from several studies demonstrated the effectiveness of these approaches in enforcing theoretical concepts and, simultaneously, providing students with examples of how to implement them in a fictional project. They are particularly suitable in teaching younger student populations and introducing them to critical thinking, scientific reasoning, and concepts, such as hypothesis formulation, data collection, experimentation, and discussion of the analysis [5]. Also, simulation is particularly useful in training students in research tasks that involve performing specific routine procedures or potentially harmful interventions. In this context, games, 3d models, and virtual environments are very beneficial in supporting research without introducing any risk for animal or human subjects. Unfortunately, poor realism is the main factor affecting most programs based on simulations. Other experiential approaches based on real-world projects, such as the unClassroom methodology, have been proposed in research courses in communication and media [6]. Most of them involve connecting students with external partners and organizations (e.g., non-profits). Particularly, the value of incorporating a service-learning component in the classroom has been discussed extensively in the literature: projects that serve the community and help address major social themes result in the best outcome [7]. Although the introduction of an experiential component appears the key element in determining student success in a program [8], there is a lack of case studies in computer science compared to other disciplines.

III. EXPERIENTIAL LEARNING METHODOLOGY

This paper presents the case study of a graduate research methods class and describes an approach in redesigning its instructional content and delivery strategy with the aim of transforming the course in an environment where individuals can learn and realize actual research studies that have a tangible scholarly outcome. The case study involves a course offered to graduate students, which is part of a set of three classes: as a pre-requisite, students complete a pro-seminar in informatics, which introduces them to basic concepts of scientific research and to techniques for designing and conducting simulated studies; then, typically, the research methods course is taken at the beginning of the last year of the graduate program; specifically, the purpose of the course is to prepare students to complete their thesis project, which is realized during the culminating capstone.

The objective of the approach was to address some of the issues of current methods classes in computer science: specifically, the guiding design principles of the course aimed at overcoming the lack of realism of simulations in EL practices. Moreover, given the level of the course and the maturity of participants, its learning outcomes involved higher cognitive and meta-cognitive knowledge domains of Bloom's taxonomy. As a result, the primary goal was to leverage experiential learning as an enabler for reaching objectives that have an impact beyond the class, as it already happens with internships or service learning, which inherently involve real-world experiences. In this regard, the purpose of the course redesign was to bridge the disconnect between traditional methods classes and tangible outputs. To this end, the experiential learning component of the course was designed based on the actual process of scholarly research and academic publishing. As a result, lectures and assignments are structured in the form of a roadmap that allows learners to transition from an applied research idea to an accomplished study that can potentially be considered for publication in an actual academic conference or scientific journal. Students start by (1) identifying a research topic and (2) reviewing the recent scientific literature, so that they can (3) design a project or study that could be (4) peer-reviewed in the form of a first draft and (5) reviewed by experts in a more mature format, in order to (6) produce a final version that is submitted to a scholarly outlet. This scheme of tasks and milestones serves as the backbone structure for designing assignments and their assessment strategy as well as for creating the instructional content, which is organized to provide students with the necessary theoretical and practical foundations for completing each step of the roadmap and achieving the final objective. The approach presented in this paper incorporates Kolb's experiential framework [2] consisting in a cycle of four activities: each milestone in the course is designed to foster opportunities for (1) having a concrete experience of the task, (2) observing the results by either reflecting on them individually or discussing in groups, (3) evaluating or reworking the output by incorporating feedback received by instructors, peers, or experts, and (4) identifying the next steps and iterations, which, in turns, enables experimenting with the process at the meta-cognitive level. As each milestone reproduces a step in the scholarly publishing workflow, course delivery, and student supervision are crucial for making sure that the experiential learning cycles result in incremental steps towards accomplishing the final objective of obtaining quality research articles that can be potentially published. As a result, rather than evaluating the individual attempt, students are given unlimited submissions, each of which is the output of an iteration. By doing this, they can document their progress, receive feedback, incorporate it in their work, plan, and execute the next iteration. Simultaneously, each submission attempt receives a temporary grade that reflects the increasing quality of their deliverables until they are satisfied with the result. This, in turn, gives them the possibility of focusing on experimenting with different methods and learning from failure without feeling the pressure to deliver their best at the first attempt to receive the top grade. As some of the objectives are particularly ambitious for the duration of the course (i.e., sixteen weeks), they were defined according to the Specific, Measurable, Attainable, Relevant and Time-bound (SMART) framework, which enabled to divide each milestone down into goals that (1) have a clear and defined scope, (2) can be graded with criteria that are generic enough to be applicable to the different characteristics of the diverse types of projects and, simultaneously, appropriate for the specific task, (3) can be achieved in the form of a very basic objective and further improvements, (4) are meaningful in terms of learning outcomes and student success, and (5) are compatible with the time available for the course and have a timeline that aligns with the content. By doing so, students have a clear overview of the general roadmap and its breakdown into individual tasks, so that they can evaluate their progress, identify strategies to stay on track, and decide on the next steps without feeling overwhelmed by the ambitious overarching goals of the course.

A. Milestone 1: project selection and proposal

Students are given complete freedom to select any research topic they want to work on. To this end, they are advised to propose a project in line with their personal interests, professional experience, current or desired job; alternatively, they can choose based on their curiosity for a specific discipline or on their willingness to explore or learn a particular subject. The only requirement for the project is that it must involve computer science in its broader sense, from sorting algorithms to the use of social media. Moreover, the research topic requires the instructor's approval before students can start working on it. To this end, the submission of a one-page preliminary proposal is required, typically by the end of week two. This, in turn, has a three-fold objective: ensuring that the research project is feasible and sufficiently relevant to the scope and level of the course, refining the idea, and, simultaneously, enforcing a deadline for starting the work, which also helps reveal and address critical situations (e.g., paralysis by analysis). The preliminary proposal has to highlight the importance of the topic (e.g., citing recent statistics and reports that highlight the dimension of the problem), summarize the state of the art and the approaches taken by others in the recent developments, and outline potential directions for contributing to the scientific conversation. Students are given the freedom to steer the focus of their work later (i.e., as discussed in milestone 3) or to completely change the topic based on the outcome of the subsequent tasks (e.g., preliminary literature review). For instance, they could realize that the solution they had in mind already exists and, thus, they could switch to evaluating its performances in comparison to other approaches; alternatively, they could realize that their lack of technical knowledge prevents them from making a significant contribution to a field and, thus, they could choose to produce an extensive literature review with a reflection on the latest developments.

B. Milestone 2. Review of the state of the art

The second milestone, usually due after week four, requires students to become more familiar with the topic by identifying and reading recent peer-reviewed scholarly articles relevant to their research topic and by summarizing their findings in a literature review document that has the purpose of narrowing the focus of their project and outlining the final objectives of their work. To this end, students are advised to use the resources available on campus (e.g., the library and the writing center), search on dedicated scholarly engines, browse the digital repositories of academic societies and communities, and explore the archive of scientific publishers and conference proceedings. Specifically, they are required to include at least the most significant 15 articles in their review and summarize and share them with the class in a short presentation in which they also discuss potential project directions based on their findings.

C. Milestone 3. Project/study design

In addition to rendering students more familiar with the domain chosen for their project and aware of the recent developments in the scientific discourse in a field, producing a review of the state of the art has the purpose of helping them finalize a decision about their project, that is, narrow the focus of their work, identify potential ways in which they can contribute, and choose the type of research approach. As for the latter, students are given complete freedom: they can realize descriptive, exploratory, correlational, explanatory, and analytical projects. As a result, their final article can review the state of the art, discuss a theory or the design of a model, implement and validate a new solution, analyze the performance of existing systems, evaluate users' perception of a technology, or combine different approaches. Also, they can decide whether their work will be experimental or non-experimental, or if it will involve qualitative, quantitative, or mixed methods. Regardless of the type of contribution they choose to make, students are typically advised to prefer applied approaches rather than pure research projects, though this is not mandatory. This is for factors related to time constraints and to the heterogeneous background of the class. Regardless of the approach chosen for their research, the requirement is that their work must result in a little yet valuable contribution to or tangible improvement in a scientific field.

D. Milestone 4. Peer review

As a fourth step, students are required to produce a first draft of their paper and have it reviewed by their classmates. As this is due by week ten, the work is not expected to be in its final form yet: thus, students are asked to structure their first draft in two parts, that is, *completed work* and *work in progress*. Depending on the type of research, the maturity of the project, availability of data, and individual commitment, the former includes sections, such as abstract, introduction, related work, methodology, and data collection, in their final version. Conversely, the latter part, which typically features the results, analysis, and conclusion section, consists of a document in the form of a working draft that is still being completed. As a result, students are expected to keep working on this part of their paper, e.g., for adding more information, incorporating feedback from the instructor, their peers, or expert reviewers, and changing the structure and content of its sections accordingly. As a second goal for accomplishing this milestone, students are required to submit their article to three colleagues for peer review. Simultaneously, when they receive a review request, students are required to fulfill it within two weeks. The objective of this task is to have students collaborate on polishing their first drafts; separating the *completed work* from the *work-in-progress* helps them review each part with a different approach: in the former, they work more in-depth on removing typos, non-scholarly references, and wrong citation style, whereas in the *work-in-progress* section they mainly check for major issues in the design and methodology. Moreover, as every project is different and the experiential nature of the course itself makes it difficult to define a specific rubric that fits every research type, the peer-review process is also utilized as a mechanism for grading students using a more general approach based on lexical correctness, adequateness of research design, consistency of methodology, accuracy of results reporting, and narrative flow. Specifically, their work is evaluated as if the reviewer and the author were on the same team: after the review is completed, if the original draft included errors and the reviewer and the author were able to identify and correct all of them, the team receives the highest points. Otherwise, if the reviewer does not identify the issue or the author does not fix it, both students are deducted points.

E. Milestone 5. Expert review

In this step, students work with the objective of having their paper reviewed by at least 3 experts. To this end, they are asked to identify researchers in the field of their project, contact them, and collect their review using a standard form provided by the instructor. The review template was designed to facilitate students in interpreting experts' feedback, discussing it with the instructor, or sharing it with the class. As they know in advance about the task, students are advised to already pre-select the list of reviewers when they research the state-of-the-art and to contact the experts and ask for their availability well ahead of this milestone. However, students can choose to wait for the peer-review to be completed before sending their drafts to experts, or to initiate this review phase while waiting for their colleagues' feedback on their work. As a result, they can concurrently realize the peer-review and expert review phases. This is to provide students with more flexibility in case they are behind schedule and to help them catch up if they required extra time in the earlier phases (e.g., project selection). The assignment is graded based on the approach to the task and, specifically, on an appropriate selection of the experts, number of requests sent, and proactive communication with them: its completion does not depend on the number of responses received by the reviewers or by their feedback.

F. Milestone 6. Presentation and publication

As a last milestone, students have to accomplish three objectives: (1) identify at least three potential peer-reviewed scholarly outlets where their work would fit and select the one they think is more suitable for their paper, (2) finalize their article using the poster or paper template required by the editor, and (3) actually submit their contribution for consideration for publication. To this end, they are invited to utilize common search engines for calls for papers, upcoming conference calendars, and solicitations for contributions from publishers and editors; also, they are advised to consider the scholarly sources where they found the articles they cited as references and to ask their reviewers about potential conferences and journals where the article would be appropriate and more likely to be accepted. As for the second objective of this milestone, they can choose the preferred format of their submission based on the available choices for the specific outlet (e.g., short or full paper, poster, or oral presentation). Moreover, although peer-reviewed scholarly outlets are preferred, in case there are no suitable deadlines, students can send their contribution to other types of non-peer-reviewed conferences and journals. Submission typically occurs between weeks 14 and 16 of the course, when they also give a final presentation to the instructor and to the class. Students are graded based on the quality of their work, and they receive points for submitting their work to an appropriate scholarly outlet, regardless of the outcome of the review process.

IV. Experimental Study

In addition to evaluating the effectiveness of the proposed strategy compared to more standard experiential learning approaches based on simulations, the objective of the study was to verify whether, given the same complexity level of learning objectives in terms of Bloom's taxonomy, more realistic and ambitious goals result in improved learning outcomes and student satisfaction. To this end, data was acquired from groups of students enrolled in the research methods class over the course of three years (2017-2019), thus, resulting in a longitudinal experimental study. The content and the approach did not change significantly over the years, though, as discussed in the next Section, small improvements were introduced over time in order to provide students with more material and examples. Two sections of the course were offered simultaneously: in presence and online, with the latter consisting of approximately two-thirds of the total enrollment. Video lectures and face-to-face meetings via remote conferencing tools facilitated working with students on a one-to-one basis, to render the learning experiences in the two classes as close as possible. All the participants in the experimental study were graduate students from the group of individuals who enrolled over the course of three years. Subjects were given the option to withdraw from the study in case they did not want to contribute or in case they identified issues in complying with some of the assignments required for completing the class. For instance, as several individuals worked on projects involving their job, they were concerned about the sensitive nature of the information analyzed in their research in case of publication. Consequently, their data is not included in this paper. The study utilized a true-experimental design: at the beginning of the semester, students were administered a demographics questionnaire that enabled to collect their gender, age, and type of program as criteria for stratified random assignment. The treatment for the experimental group consisted in the set of milestones described in the previous Section, whereas the control group was not expected to work on real-world scientific project (i.e., they could replicate or simulate a study), and did not have any commitment in terms of expert review (Milestone 4) or submitting their contribution for publication (Milestone 6). A pre-course survey asked them questions about their motivation, objectives, and perception of their competences, whereas the post-course included additional items related to learning outcomes and perceived satisfaction that were utilized to evaluate the effectiveness of the treatment. Also, the turnaround time and the number of iterations required to accomplish a satisfactory result were acquired.

V. Results and Discussion

The data analysis is based on the model presented in [9], and it evaluates the overall student satisfaction, learning outcomes, and perceived difficulty in the different phases based on the dimensions of (1) student's intrinsic and (2) extrinsic motivation, (3) student self-regulation, (4) student-instructor dialogue, (5) student-student dialogue, (6) instructor activities, and (7) course design. Specifically, intrinsic motivation includes factors, such as personal interest and professional goals, whereas extrinsic motivation was associated with the primary intent of taking the required methods class to finish the program and graduate. Self-regulation was calculated in terms of time dedicated to the project compared to the available time in the semester; also, adherence to milestones and their timeline was taken into consideration. In addition to student-instructor dialogue and student-student dialogue, student-expert dialogue was considered as a measure of interaction. Instructor activities were evaluated in terms of perceived quality of course delivery, whereas course design specifically referred to the overall structure of the class and, particularly for the experimental group, to milestones 1, 5, and 6. As reported in Figure 1, both groups were satisfied by the course, though they also perceived it as one of the most challenging classes in the program. However, while the experimental group shows a statistically significant difference (P=0.021) in terms of satisfaction compared to the control group (+13%), there is little difference between the groups in terms of perceived difficulty. Students' responses show that being able to work for tangible objectives and achieve them was a motivator. The difference between the experimental and the control groups can be particularly appreciated when considering the learning outcomes and, specifically, the perceived level of expertise at the beginning and at the end of the course (see Figure 2). In this regard, the average of the experimental group (61% and 95%, respectively) showed a 35% increase, whereas the control group (61% versus 89%) had a 28% improvement. In this regard, responses from the experimental group highlighted that the experience, and especially interaction with experts (as discussed later), helped them become more proficient. Small differences were found between the groups in terms of factors that had the most impact on success (Figure 3). However, the control group is more polarized, whereas students in the experimental group realized the importance of all the components of the learning experience. Furthermore, each step in the process was analyzed from a quantitative and qualitative standpoint to evaluate student satisfaction and learning outcomes and to identify the activities that were perceived as having the most value for students (Figure 4). Surprisingly, in the control group, the value of the activity aligns with the effort required to complete it. As a result, the review of the literature (M2) and the project/study design account for 84% of the total milestones. Conversely, students in the experimental group realized the value of each milestone. Particularly, M5 (student-expert dialogue) and M6 (presentation and publication) scored 22% and 15%, respectively. This reflects the content of several responses in which students mentioned that the interacting with an expert and being able to realize a real-world publication motivated them to learn more and improve the quality of their work.

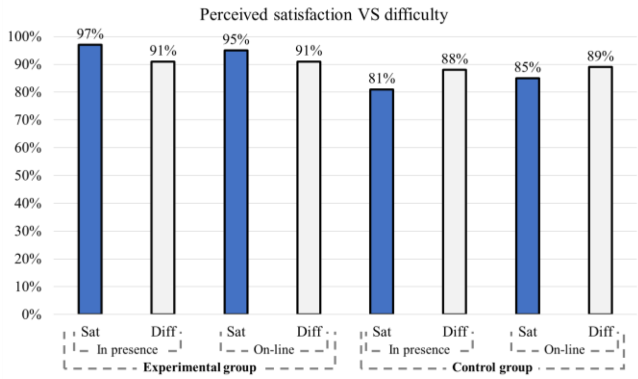

Figure 1. Perceived satisfaction (Sat) and difficulty (Dif) in the experimental and control groups in face-to-face and online classes.

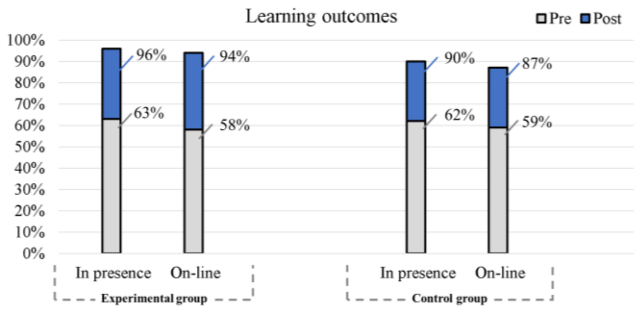

Figure 2. Perceived proficiency with research methods at the beginning (Pre) and at the end (Post) of the course.

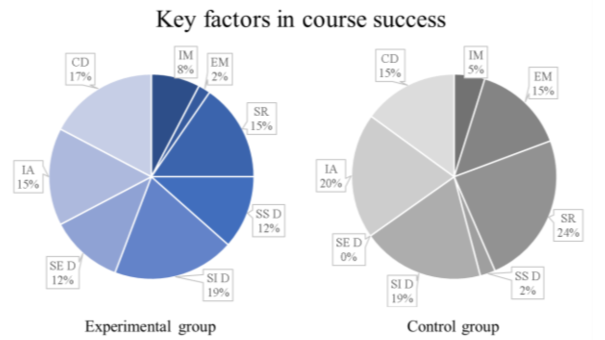

Figure 3. Perceived factors of success: intrinsic (IM) and extrinsic motivation (EM), self-regulation (SR), student-instructor dialogue (SI D), (5) student-student dialogue (SS D), student-expert dialogue (SE D), instructor activities (IA), and course design (CD).

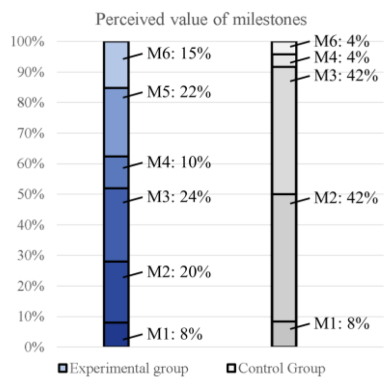

Figure 4. Perceived value of the milestones of the course in terms of learning outcomes: project selection and proposal (M1), review of the state of the art (M2), project/study design (M3), peer review (M4), expert review (M5), and presentation and publication (M6).

Students especially enjoyed the possibility of working on their own proposals rather than being assigned to a topic. Most of them were able to independently select a project that was suitable for the course in terms of objectives and workload. Data about the initial selection show that this task was challenging for all the students, regardless of the group. This is in line with research on higher cognitive tasks in Bloom's taxonomy and reinforces the idea that aiming at more ambitious goals did not result in any additional overhead for the experimental group. Moreover, the results show that at the beginning of the class, students in both groups had poor confidence in their skills and lacked familiarity with the process of scholarly research. Defining a direction for their research after reviewing the literature was perceived as the most difficult task. Nevertheless, the data do not show any significant difference between the experimental and the control groups in terms of perceived discomfort, which supports the argument that introducing more ambitious and specific goals that have the same complexity (from a Bloom's taxonomy standpoint) does not result in additional burden for students. Also, the data show an improvement in terms of satisfaction over the years: this is because students were provided with more examples of the deliveries expected as an output (articles written by alumni from previous years). Students were enthusiastic about the idea of peer review: the challenge of working in a team with others, primarily resulted in an incentive to complete the task appropriately. Also, this gave them the opportunity of exploring other topics as well as comparing their work to the research done by others. Furthermore, this activity resulted in the highest engagement and was perceived as helpful to increase the overall quality of submissions. As shown by Figures 3 and 4, the selection of external reviewers was particularly interesting from a learning outcome standpoint. Also, students were able to perceive its value. Moreover, this task provides a unique opportunity to introduce topics that the course would not otherwise explore, such as conflict of interest: for instance, several students initially selected their relatives or coworkers as reviewers. Moreover, receiving opinions from experts other than the instructor was useful for having students understand how their work would be perceived in a professional environment, for increasing their awareness on the quality of their deliverables, and for having an external stakeholder hold them responsible. Fortunately, most experts agreed to act as reviewers, which, in turn, gratified students and increased their self-confidence. Also, student-expert communication resulted in the most significant improvement in the quality of submissions.

VI. Conclusion

This paper presented the case study of the redesign of a research method course in computer science using an experiential learning approach, especially aimed at stimulating students to realize actual research projects. Specifically, the proposed strategy requires them to accomplish ambitious SMART goals that culminate in potentially publishing the results of their work in an academic conference or scientific journal. The paper outlined the motivations of the work, the teaching methodology, and the expected outcomes. Moreover, it presented the results of an experimental study that measured the effectiveness of the approach over several dimensions of student success. Based on the analysis of 3 years of data, the findings of this study show that exploring real-world projects results in better engagement with course content. Also, the findings support the argument that as research methods classes stimulate higher cognitive levels of Bloom's taxonomy, learning experiences can also incorporate ambitious real-world objectives that produce tangible outputs beyond the classroom.

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