Students' Perceptions of Applying Real-world Problem Solving in Computer Science Education

Case Study in Interaction Design

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Abstract—**Computer science is pervasive, being present in daily life. Computer science students need to develop skills to solve computational problems involving real-world applications. The study presents an exploratory case study that examined the perceptions of computer science students towards real-world problem solving. The participants were 72 computer science graduate students in a human-computer interaction course during two semesters. The students were immersed in a real-world problem solving educational situation. After, a quantitative study was conducted, with data obtained from a questionnaire. Data from the questionnaire revealed that the perspectives of computer science students concerning real-world problem solving are positive. The students recognized that the tasks were valuable, did not present difficulties, were engaged, had fun, attributed long-term importance, judged that the tasks fit their personal development, and it was worth to devote their time and resources. In summary, students in our samples hold the opinion that real-world problem solving provides a meaningful learning experience. The findings provide new insights into the opportunities of the application of real-world problem solving in computer science education.**

Keywords—computer science education; real-world problem solving; contextualizing computer science; students' perceptions

I. Introduction

Computer science has become an essential tool in all areas of human life. From engineering and physics traditional fields of application to biology, medicine, economics, arts, journalism and more unusual fields like criminology or fashion. The world becomes progressively more digitized and interconnected, with smart phones and smart homes continually computing something for us, intelligent systems that control transportation and production, and decision support systems that takes care of our safety and well-being [1].

We have witnessed a crescent dissemination of information technology tools and systems in homes, public spaces, communities, workplaces and organizations. The advents of wireless communications have widespread everyday use of computers and information systems. Whereas engaging in a computer application once conceived at printing "Hello, World!" to the screen or implementing a binary search algorithm, computer science field has grown to include a variety of technologies such as collaborative or social platforms, and a Internet of Things that students can enact to. With these new contexts come new opportunities to introduce learners to computer science [2].

However, the growing diversity of topics potentially relevant to an education in computer science and the increasing integration of computing with other disciplines also trigger new challenges for computer education. Students need to acquire the ability to smartly use computer technology. A graduate in computer science must break conventional knowledge silos and train qualified personnel who are better able to apply computational techniques to a wide variety of problems in several areas of knowledge [3].

Computer science courses should not only prepare students for a traditional academic career, but must also meet a need for highly trained staff in business and industry. Students must develop the ability to understand the context of a practical problem, and then define it in terms that can be understood and agreed by the system user, commonly having a different background. Students are required to use technology inventively to give the most effective and innovative solution to a problem. A call for these skills has been documented in numerous studies. There is a demand for graduating a professional who can contribute to the global setting for the economy and society [3].

A successful implementation of information technologies demands well-prepared professionals who are able of creating high-quality efficient computational solutions and intelligently apply computational knowledge at the labor market. Therefore, there is an urgent need to reconsider the educational objectives in the field of information technologies. [4].

Additionally, it is widely recognized [5] that computer science will play a critical role in the future of the scientific discovery process if programs prepare students for careers in industry, education, and science. Teachers from computer science courses should teach students to construct

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computational models of real-life observations, to turn these models into computational codes. These skills are in high demand all over the world, both in industry and academia.

II. Related Work

In order to prepare the students to create efficient computational solutions, teachers should embrace a contextualizing computer science educational perspective. There are many approaches that advocate a computer science educational focus on computational thinking [2][6][7][8][9]. Computational thinking describes the mental activity in the formulation of a problem to admit a computational solution. Under this perspective, computing is not interpreted as simply algorithms, databases or other purely technical knowledge. On the contrary, the term computer science essentially defines an area that is intended for the use of computers with application in some other area, or, colloquially speaking, "Computers and other area". Thus, unlike conventional computer science courses, teachers should focus primarily on traditional computing and algorithm development in other areas [3].

Computer science education literature is more and more contextualizing computing in other areas. The IEEE/ACM joint task force on computing curriculum recommends this practice in their new Curriculum 2013 proposal as a way of highlighting the application of computer science to areas beyond traditional jobs, amplifying the appeal of computer science [10].

An educational focus on contextualizing computer science, where students are encouraged to solve real-world problems is a current trend. New academic programs have emerged, intending that students gain experience in designing computational systems in libraries, health, business, education, government, and others. These new programs aim at educating broad-minded practitioners rather than expert programmers in the field of information systems.

[11] describes a program that advocates industry-university cooperation is an effective way to develop students' competences required by companies. In [12] study, undergraduate students in CS and journalism courses focus on creating a computational solution to address a real community need. [13] utilizes mathematical modeling of the studied processes and phenomena using mathematical application software packages. [14] implements computational games that investigate ill-structured problems and their causes. The program in [15] seeks to be sensitive to the increasing demand for higher education of the population in a rural part of the country, by considering the multi-cultural facets of businesses, organizations, and communities, and to empower these developing communities by using advanced technologies and information systems.

This new educational strand, that adopts computer science in context, converge to a teaching approach encompassing real-world context or phenomenon, aiming to motivate the students, to open connections to prior knowledge or to show application situations of the intended knowledge. Real-world problems have a vague definition of purpose, with little restraint, ill-structured by nature. Ill-structured problems have multiple solutions, different solution paths, fewer parameters that are less manageable, and may contain uncertainties about which concepts, rules, and principles are needed for your solution or how they are organized, and which solution is best [16]. Ill-structured problems are underspecified, demanding the formulation of multiple hypotheses, and the search for information to refine these hypotheses towards a solution. Real-world problem solving opens to multiple perspectives among students unveiling many solution paths to be explored.

Commonly, computer science teachers and curricula provide more guidance and practice in solving well-structured problems, especially in the first semesters of study [17]. Well-structured problems are well-defined, including the supply of materials from a variety of sources and application of a systematic approach to solve the problem. Well-structured problems are constrained problems with convergent solutions that engage the application of a limited number of principles involving well-defined parameters [16].

Computer graduates need to understand how to apply the knowledge they have gained to solve real problems, not just write code. They should be able to design and improve a system based on a quantitative and qualitative assessment of their functionality, usability and performance. They must solve ill-structured problems with the aim to realize that there are multiple solutions to a given problem and have the opportunity to exercise scientific research and critical thinking [18].

III. The Study

Given the importance of the real-world problem solving application in the educational context, the objective of this work is to offer clues regarding the students' perspective of real-world problem solving adoption. Our aim is to provide insights into what can be expected from computer science students during real-world ill-structured problem solving, unveiling if the students can have a meaningful learning experience directly influencing their motivation. We intend to reveal if the students show empathy to a less structured problem solving, and to show the students' perceptions of the learning gains, self-efficacy for learning, task value, performance and gratification.

Our justification for focusing students' perspectives is to verify if real-world problems are able to draw favorable attention and motivate the students, instigated by the fact that they tend to be meaningful and applicable to students' lives. Research provides evidence that the level of student's motivation affects student enjoyment of activities, performance and levels of engagement with a task [19]. Students' positive emotions, task immersion, approach behavior, and long-term interest are crucial aspects of learning and essential for academic success, involving conducive factors that stimulate students to be continually interested and committed to a learning task, or to make an effort to achieve a goal [20].

A. Method

This work reports an exploratory case study that was conducted with the objective to show the student perceptions of his/her learning experience when solving a real-world problem. The case study involved seventy-two undergraduate computer science students, during two semesters of a human-computer interaction course. There were thirty-two students in one cohort and thirty students in the other cohort. This course was chosen for the case study, because it is one of the few courses in computer science where real-world problem solving is traditionally applied. This work intends to show the positive impact of this strategy on students' experience, in order to motivate teachers from other computer science courses to adopt a real-world contextualized approach.

In both semesters the students were under the same conditions. We repeated the case study twice aiming to make the results more reliable. The students were asked to develop a prototype of an App for task management to be used by students during group work assignments. The students participated in five sequential study sessions.

In the first session, the students applied a questionnaire to other students for requirement gathering. During the second session, the students analyzed six existing Apps for task management at workplace. The objective in this phase is to motivate the students to exercise the adaptive creativity, choosing and adapting some functionality from the professional context to the academic context. At the third session, the students were asked to elaborate Storyboards, showing how a user might interact with the App and progress through the user tasks. The fourth session included detailed formal lectures about up-to-date design patterns for mobile applications, and, finally, in the fifth session, the students created and presented the App prototype, as a refinement of the storyboard and application of the design patterns.

A User eXperience (UX) questionnaire was applied to the students to evaluate the students learning experience during the App development throughout the five sessions mentioned. The questionnaire is based on categories from UX dimensions [21] and takes into account motivational and behavioral aspects of the educational experience, such as emotions involved, needs fulfillment, intentionality, value attached, and goals fulfillment. The UX categories approached during the questionnaire elaboration were:

1. Immersion and focus of attention. Related to how much the student is engaged and involved during the learning tasks.

2. Competence. Related to goal fulfillment, confidence, achievement and pride.

3. Emotional experience. The student can show positive or negative affect, more or less intensely. For, example, the learning experience can be fun, pleasant and goal conducive or boring and unpleasant.

4. Challenge. The student puts effort while performing the tasks, but he/she takes pleasure in overcoming obstacles.

5. Discovery. The student is happy to deal with new things.

6. Expression. Linked to identity, student relatedness and attachment.

7. Valuing. The perceived worth, usefulness and utility of the learning task.

8. Responding to Phenomena. Related to responses to stimulation, intention to act, long term importance and approach and avoidance behavior.

The UX Questionnaire is described as follows:

1. Does interaction design sound more interesting after had attended this course?

2. Would working with interaction design be interesting?

3. Is interaction design a too difficult subject for you?

4. Does interaction design seem silly for you?

5. Does interaction design require too much work compared to other computer science applications?

6. Is interaction design not well suited for a computer scientist? Is it more suited to another professional, like a designer?

7. Has interaction design anything to do with your life?

8. Has this interaction design course contributed to your academic background?

9. Has this interaction design course contributed to your professional background?

10. Do you prefer practices involving well-defined problems and coping with typical study requirements rather than real world ill-defined problems?

11. Do you think that applying real world problem solving in computer science classes should happen since the first study semester, because it is more creative and promotes a broaden view of computer science?

12. Has this course helped you to break the belief that clear and unambiguous answers are omnipresent in computer science?

13. Was solving a real-world problem fun? Are you pleased with the experience?

14. Were you more motivated to perform the tasks comparing to more traditional assignments?

15. Has real-world problem solving improved your computer science skills?

16. Have you accomplished the tasks effectively?

17. Has this real world problem-solving experience fit within your personal development?

18. Has it been a positive and engaging experience?

19. Has this experience contributed to your understanding of interaction design?

20. Despite being challenging, has this experience changed positively your attitudes towards software development?

21. Do you intend to continue learning interaction design in the future?

The conceptual mappings between the questions and categories are: question 18 is linked to engagement category; questions 3, 5, and 16 to competence category; questions 10 and 13 to the category involving the emotional aspect; questions 10 and 20 to challenge category; questions 11, 12 and 20 to discovery category; questions 6, 7, 15 and 17 to expression category; questions 1, 4, 8, 9, 10, and 19 to value category; questions 2, 14, and 21 to responding to phenomena category.

B. Results

The main goal of the present study was to explore the students' perspective of the impact of real-world problem solving. Understanding students' perspectives on their real-world problem solving behavior and motivation is an important addition to experimental studies in the computer science education field, because results can broaden our understanding of this learning approach. Conclusions will help when it comes to designing future educational approaches.

TABLE I. PERCENTAGE OF STUDENT RESPONTES FROM COHORT 1.

Questions	Category of Responses				
	Strongly Agree	***Agree***	***Neutral***	***Disagree***	***Strongly Disagree***
1	61.111	30.556	2.778	5.555	0.000
2	55.556	30.556	5.555	5.555	2.778
3	0.000	2.778	0.000	44.444	52.778
4	2.778	5.555	0.000	61.111	30.556
5	0.000	41.667	8.333	27.778	22.222
6	0.000	5.555	5.556	63.889	25.000
7	0.000	0.000	2.778	36.111	61.111
8	80.556	11.111	8.333	0.000	0.000
9	27.778	63.889	8.333	0.000	0.000
10	41.667	44.444	8.333	2.778	2.778
11	36.111	50.000	13.889	0.000	0.000
12	33.333	61.111	5.556	0.000	0.000
13	36.111	47.222	8.333	2.778	5.556
14	25.000	50.000	13.889	11.111	0.000
15	33.333	63.889	2.778	0.000	0.000
16	22.222	75.000	2.778	0.000	0.000
17	33.333	61.111	5.556	0.000	0.000
18	69.444	27.778	2.778	0.000	0.000
19	22.222	75.000	0.000	2.778	0.000
20	16.667	83.333	0.000	0.000	0.000
21	36.111	61.111	2.778	0.000	0.000

This study supports the expectations that real-world problem solving is an effective strategy to provide a good student experience by, emphasizing self-expression, motivation, students' interest, and discovery. An exploratory case study involving 72 students distributed in two cohorts, found evidence for the positive impact of real world problem solving on students.

TABLE II. PERCENTAGE OF STUDENT RESPONTES FROM COHORT 2.

Questions	Categories of Responses				
	Strongly Agree	***Agree***	***Neutral***	***Disagree***	***Strongly Disagree***
1	41.177	55.882	2.941	0.000	0.000
2	44.118	44.118	8.823	0.000	2.941
3	0.000	2.941	11.765	70.588	14.706
4	14.706	0.000	0.000	14.706	70.588
5	0.000	0.000	5.882	44.118	50.000
6	0.000	0.000	0.000	14.706	85.294
7	0.000	0.000	0.000	35.294	64.706
8	82.353	17.647	0.000	0.000	0.000
9	44.118	55.883	0.000	0.000	0.000
10	2.941	0.000	8.824	55.882	32.353
11	38.235	50.000	8.824	0.000	2.941
12	47.059	47.059	5.882	0.000	0.000
13	44.118	50.000	0.000	0.000	5.882
14	32.353	55.882	2.941	8.824	0.000
15	44.118	55.882	0.000	0.000	0.000
16	14.706	85.294	0.000	0.000	0.000
26.471	73.529	0.000	0.000	0.000	26.471
55.882	44.118	0.000	0.000	0.000	55.882
55.882	44.118	0.000	0.000	0.000	55.882
47.059	52.941	0.000	0.000	0.000	47.059
47.059	50.000	0.000	0.000	2.941	47.059

Fig. 1. Student's responses from cohort 1.

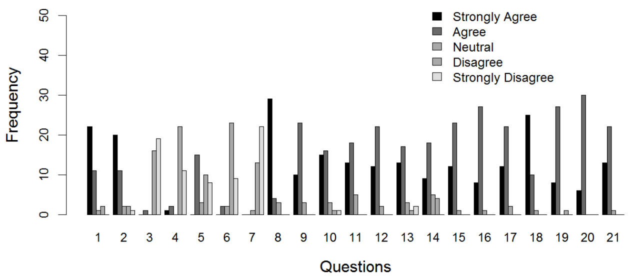
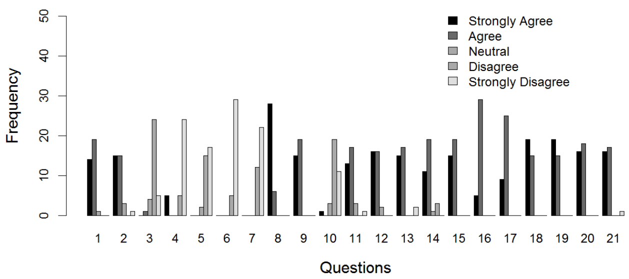


Fig. 2. Student's responses from cohort 2.



As shown in Table I, Table II, Figure 1, and Figure 2 similar pattern of answers was found for both cohorts. A corresponding perspective was found, where answers from students in the cohort 1 were as positive as responses from students in cohort 2. Students in both cohorts proved to be aware of the benefits and potential of real-world problem solving. Following, we discuss the results described in Table III and Figure 3, regarding the two samples.

TABLE III. PERCENTAGE OF STUDENT RESPONTES FROM COHORTS 1 AND 2.

Questions	Categories of Responses				
	Strongly Agree	***Agree***	***Neutral***	***Disagree***	***Strongly Disagree***
1	51.429	42.857	2.857	2.857	0.000
2	50.000	37.143	7.143	2.857	2.857
3	0.000	2.857	5.714	57.143	34.286
4	8.571	2.857	0.000	38.572	50.000

5	0.000	21.429	7.143	35.714	35.714
6	0.000	2.857	2.857	40.000	54.286
7	0.000	0.000	1.429	35.714	62.857
8	81.429	14.285	4.286	0.000	0.000
9	35.714	60.000	4.286	0.000	0.000
10	22.857	22.857	8.571	28.571	17.144
11	37.143	50.000	11.428	0.000	1.429
12	40.000	54.286	5.714	0.000	0.000
13	40.000	48.571	4.286	1.429	5.714
14	28.571	52.858	8.571	10.000	0.000
15	38.571	60.000	1.429	0.000	0.000
16	18.571	80.000	1.429	0.000	0.000
17	30.000	67.143	2.857	0.000	0.000
18	62.857	35.714	1.429	0.000	0.000
19	38.571	60.000	0.000	1.429	0.000
20	31.429	68.571	0.000	0.000	0.000
21	41.429	55.713	1.429	0.000	1.429

Considering Table III, we found that 51.42% of students strongly agree and 42.85% agree that interaction design sounds more interesting after having attended this course. Furthermore, we found that 50% of students strongly agree and 37.14% agree that working with interaction design would be interesting.

In addition, 57.14% of students disagree and 34.28% of students strongly disagree that interaction design is too difficult. Also, most of the students disagree or strongly disagree that interaction design requires too much work compared to other applications of computer science.

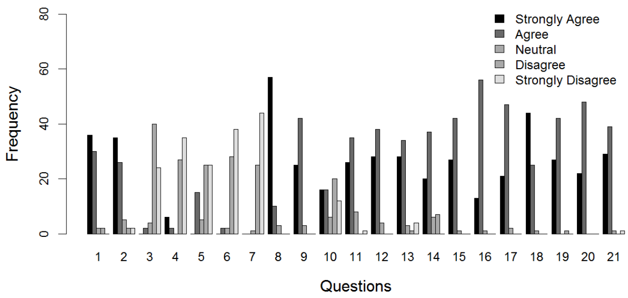
Most students said that interaction design is well suited for a computer scientist, has to do with their lives, and that the course contributed to their academic and professional background.

Of the 72 students responding, approximately 46% showed preference in practices involving ill-defined problems and coping with typical study requirements rather than real world ill-defined problems against 46% that did not show preference. However, approximately 88% think that applying real world problem solving in computer science classes should happen since the first study semester, because it is more creative and promotes a broaden view of computer science, and 94% said that the course helped them to break the belief that clear and unambiguous answers are omnipresent in computer science.

Regarding the percentages in Table III, we can see that most of students had fun during the execution of activities, considering the experience positive and engaging. It can also be seen that approximately 81% of them was more motivated to perform the tasks comparing to more traditional assignments.

Table III shows that the most of students thinks that solving a real world problem improved their computer science skills and that this practice fit within their personal development. Additionally, the majority of students intend to continue studying interaction design in the future.

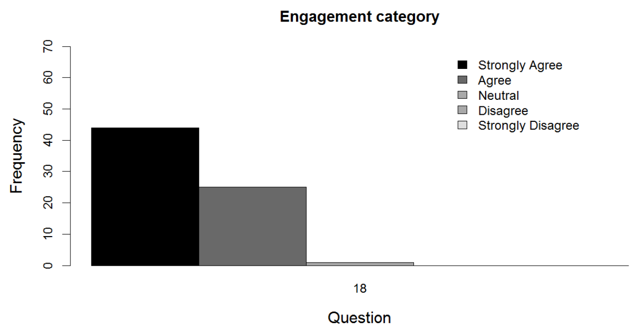
Fig. 3. Student's responses from cohorts 1 and 2.



As shown in Figure 3, answers to the questions indicate the students' perceptions in eight UX categories: engagement, competence, emotional aspect, challenge, discovery, expression, valuing, and responding to phenomena.

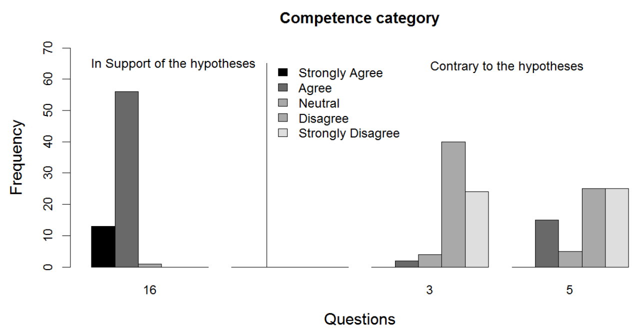
Concerning engagement category (Figure 4), a fundamental condition for learning, we found that students perceived the use of real-world problem solving as beneficiary to task immersion. They noticed themselves as having an enhanced focus during the tasks.

Fig. 4. Student's responses from cohorts 1 and 2 regarding the engagement category.



With regard to competence category (Figure 5), students in our samples viewed themselves as competent real-world problem solvers. The students felt able to achieve the best possible outcomes. They perceived their tasks performance effective. They neither found the tasks difficult, nor assessed interaction design as being demanding compared to other computer science tasks.

Fig. 5. Student's responses from cohorts 1 and 2 regarding the competence category.



About emotional aspect category (Figure 6), the results indicate a positive emotional effect of real-world-problem solving. Students reported high levels of enjoyment and a preference for solving ill-structured problems. The positive affect experienced by students can increase their persistence, which in turn leads to better learning outcomes.

With reference to challenge category (Figure 7), students showed that despite being challenging, real-world problem solving has changed positively their attitudes concerning software. This finding is in line with the assumption that the intrinsically ill-structured real-world problem solving challenges students immersing them in an unpredictable situation. However, suggesting that new perspectives emerge and successfully impact the learning processes.

Fig. 6. Student's responses from cohorts 1 and 2 regarding the emotional experience.

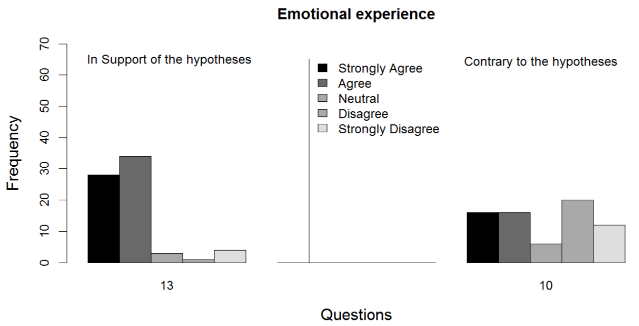
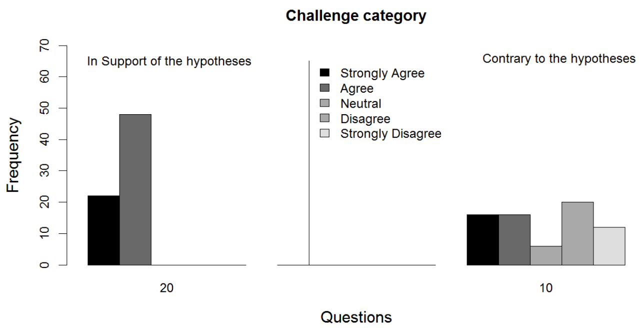


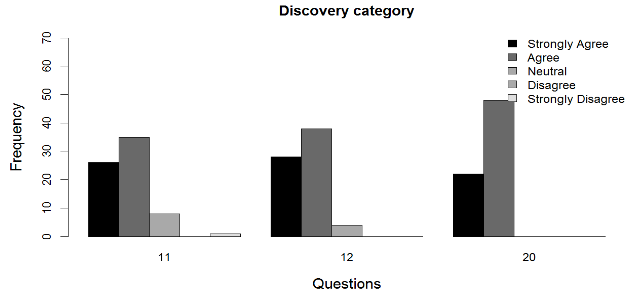
Fig. 7. Student's responses from cohorts 1 and 2 regarding the challenge category.



According to the results, the students perceived the threatening components as a contributing factor to his/learning. They accounted that learning was positively affected. Beyond that, in spite of the students are used to being provided with well-defined constraints instead of being challenged with ill-structured problems, they coped well with this educational strategy.

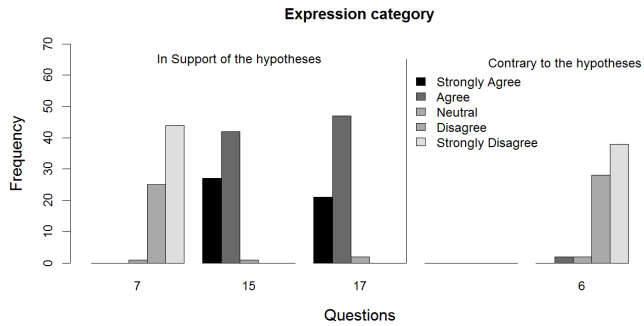
Respecting discovery category (Figure 8), the students reported that the real-world problem solving experience enhanced their awareness of the computer science applications. In addition, the results identify a general change in the way the students perceives software development and importance. Students in our samples were able to enrich personal development.

Fig. 8. Student's responses from cohorts 1 and 2 regarding discovery.



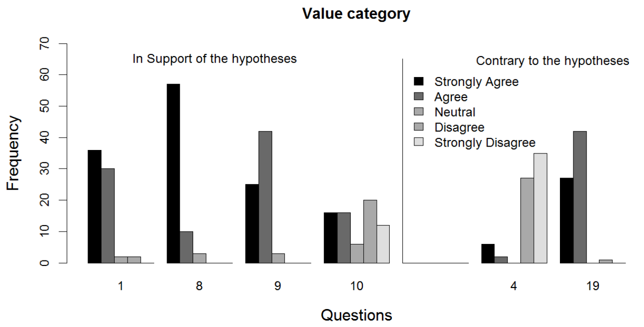
In the matter of expression category (Figure 9), even in a supposedly fun and innovative context, the relationship between the object of the activity and the students' needs is crucial to promote engagement and learning. Students judged that the learning experience fit their personal development. Moreover, students point out that the course suits the requirements to become computer scientist.

Fig. 9. Student's responses from cohorts 1 and 2 regarding the expression category.



Relating to valuing category (Figure 10), we observed that students considered real-world problem solving a more relevant experience, despite being used to solve well-structured problem solving. Besides, the student considered that their involvement in the real-word problem solving practice implied in a positive change in previous ideas regarding the course subject, a great contribution to their professional background, a significant increase in their knowledge to the course subject. In that case they perceived the learning experience worth to devoting their time and resources.

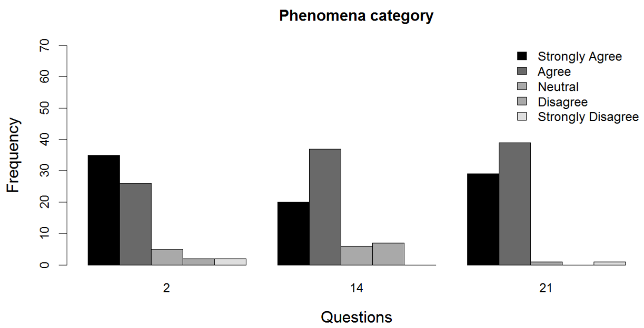
Fig. 10. Student's responses from cohorts 1 and 2 regarding the value category.



Regarding responding to phenomena category (Figure 11), bearing in mind long-term importance, intention to act, and responsiveness, students pointed the learning experience influential to these factors. Students assumed that they were more motivated to perform the tasks comparing to more traditional assignments. Students found that working in the area of the activities covered during the course would be interesting. Additionally, they demonstrate intention to continue learning the course subject in the future.

Several important aspects were identified from the current study. The first aspect investigated concerns the students' perceptions of the motivational and affective influence of the real-word problem solving. The second level concerns to what extent the students perceived that the real-word problem solving contributed to their learning experience. Third, this works copes with students' intentions during and after the leaning tasks.

Fig. 11. Student's responses from cohorts 1 and 2 regarding the responding to phenomena category.



In summary, students in our samples hold the opinion that real-world problem solving provides a positive learning experience. In sum, they are knowledgeable about the benefits of this educational practice. This research suggests that some fundamental students' needs, as indicated by their responses to the questionnaire, actually materialize during real-world problem solving activities.

In general, students seemed to experience a good UX when solving an ill-structured problem. Therefore, teachers should be optimistic concerning the application of this learning approach.

IV. Conclusions

Identifying and taking into account students' needs and expectations is reinforced as an indispensable step in educational new trends. It is worthwhile to raise students' perspectives of the adoption of real-world problem solving in learning computing. The application of real-world problem solving in learning contexts is an educational perspective that privileges a contextualizing computer science, being imperative to enable graduates to create high-quality efficient computational solutions.

The present study examined the perspectives of 72 computer science students towards online real-word problem solving in a human-computer interaction course. Our study indicates that the application of real-world problem solving promotes a good learning experience.

This study focused on 8 UX categories (engagement, competence, emotional aspect, challenge, discovery, expression, value and, responding to phenomena) from the point of view of students. Having in mind the UX categories a questionnaire was developed.

Question 18 measured the students' perceived abilities to engage in the computational practices. Questions 3, 5, and 16 were used to evaluate how competent the students felt during the tasks. Questions 10 and 13 served to assess students' emotional aspect. Questions 10 and 20 delivered information to examine how the students dealt with challenging situations. Questions 11, 12 and 20 were used to determine if the students were involved in discovery processes. Questions 6, 7, 15 and 17 were used to unveil students' affinity to the tasks. Questions 1, 4, 8, 9, 10, and 19 generated data to weight the value the students attributed to the learning activities. Questions 2, 14, and 21 were used to view how students responded to the tasks, how was students behaviors, and if they attributed long-term importance to the learning experience.

The study highlights the importance of engaging students in the real-word problem solving and sheds light on their needs and expectations indicating this educational practice as conducive to an effective learning experience. The data generated from questionnaire reports that students perceive real-word problem solving as an adequate strategy to foster students' positive emotions, task immersion, motivation, approach behavior, and long-term interest.

Contextualizing computer science promotes skills required both in industry and academia. Teachers from computer science courses should teach students to construct computational models from real problems. This study suggests that teachers might apply real-world problem solving as successful attempt to embrace a contextualizing computer science as an educational strand.

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