A Hackathon Methodology for Undergraduate Course Projects

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***Abstract*—In this innovative practice full paper we present a methodology for organizing a hackathon as a learning instrument within the scope of an undergraduate course. Hackathons are short events (1 to 3 days), where participants motivated by a common challenge gather into groups to build a software or hardware prototype. Studies show that learning is one of the main motivators of hackathon participants. Researchers are also pointing out the importance of hackathons as an informal learning approach for college students. The acquisition of knowledge comes as a result of the practice itself and with participants learning from one another. This motivated us to bring that practice to the classroom, by offering an undergraduate course where students develop their semester project within a hackathon. In an attempt to systematize the steps, compress and optimize the time allocated for the ideation phase of hackathon projects, we propose a methodology for hackathons in an educational setting. The approach combines concepts from Challenge-based Learning and Design Thinking in a sequence of activities that streamlines the ideation process with regular deliveries in short time frames. This results in objective discussions and quick decision taking, fastly arriving at a project idea where students apply what they learned over the semester. We applied our approach in an Internet of Things undergraduate course within the scope of a semester project developed in an authentic 24-hour hackathon that took place in a maker space. This article details the methodology and presents a mixed methods study to analyze the students' perception on using this set of practices and techniques.**

***Index Terms*—hackathons, experiential learning, self-regulated learning, project-based learning**

I. Introduction

Hackathons are continuous events that engage people in small groups to produce software in a limited amount of time, typically lasting from 1 to 3 days [1]. These events gained popularity in technology companies in the 2000s as a way to promote exploratory coding, new idea generation, and prototyping with low-risk [2]. Activities such as hackathons, coding marathons and similar ones that present challenges to solve problems can be a powerful tool for engaging students into competition and collaboration, complementing the formal learning that takes place in classrooms [3].

However, hackathon participants commonly deal with issues concerning (1) the distance from actual user requirements on the projects they developed and (2) the time to make a fully functional prototype. Lee et al. [4] claim that developers participating in apps competitions have limited perspective on user problems. This was confirmed in another study reporting that hackathon participants may become the stakeholder of their projects based only on their own experience instead of actual stakeholders or potential users [5]. Concerning the time issue, projects in these events usually end up as incomplete. A multiple case study of three scientific hackathons found that very often the projects were not finished [6]. Although having a very short timespan, projects developed in hackathons may suffer from the effects of Parkinson's law: *"work expands so as to fill the time available for its completion"* [7].

As an observation of one of the authors of the current paper, who has organized several hackathons outside the university, teams many times strive to ideate their solutions in those venues. The initial project definition phase, with typically random activities, does not stimulate the search for requirements from a user's perspective and, also, may take a few hours before team members know what features and what artifact is going to be developed by the group. In short hackathons (e.g. 24 hours) this is critical since there is not much time to conceive the prototype to be presented at the end of the event, many times leading to frustration.

In this paper, we introduce a methodology to be used in project-oriented undergraduate courses where a hackathon dynamic can be employed as a realistic scenario to practice the knowledge acquired in classes. It quickly allows students to come up with a project idea having a purpose, aligning course goals with students' interests. We combine Challenge-based Learning (CBL) concepts and Design Thinking techniques to accelerate the ideation of hackathon projects, systematizing the conception of ideas to transform them into solutions.

We applied the proposed methodology in a hackathon where Computer Science and Information Systems undergraduate students developed the final project of an Internet of Things (IoT) optional course. During a 24-hour period, 22 students divided into seven groups participated in an authentic hackathon in a maker space. Students had to look for practical problems, identify potential stakeholders to propose IoT solutions for them. We report the results of the mixed methods approach employed to collect students' opinions about the methodology that was used to conduct this hackathon. This article focuses on the hackathon methodology itself, being complementary to our previous work [8] where the perspective on the influence of a hackathon in the learning process is analyzed.

The remainder of this paper is organized as follows: section II provides background on some of the topics explored. Section III details the methodology of our study. Section IV explains the empirical approach, and section V presents our results that are discussed in section VI. Section VII concludes the article.

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II. Related work and Background

A. Hackathons and Learning

Experiential learning considers learning as a continuous process grounded in experience that has to take into account the environment in which the learner is inserted [9]. In the Situated Learning model, learning is social and comes mainly from of one's experience of participating in daily life [10]. The 'communities of practice' represent groups of people sharing a concern or a passion for something they do; learning how to do it better as they interact regularly [11]. Hackathons are a great example of an instructional strategy allying practical, contextual and social aspects of this contemporary pedagogical mindset in an engaging learning experience. Different perspectives focusing on the importance of hackathons for college students as another venue for practicing and learning can be found in the literature. Similarities between hackathons and project-based learning have also been found [12], with highlights on the self-regulated learning that takes place. Hackathons were also used to put students in contact with professionals from their field to build together software focused on socially relevant issues [13]. It fostered work-integrated learning, stimulating students in their course.

Peer learning can be found in college hackathons [14], where students can teach and learn from their peers. Also, due to the short duration of the event, they improve their skills in problem-solving, project management and task priority analysis. The aspect of learning from peers has been confirmed in a study also focused on college hackathons [15], where learning was happening incidentally and opportunistically, with students motivated by both social and technical reasons.

To the best of our knowledge, few studies claimed the usage of hackathons in the classroom. We found approaches on teaching Web Application Development [16] and Mobile Development [17], for instance. However, the so-called hackathons in these cases were limited to the duration of a regular class (120 to 150 minutes), which is much shorter when compared to an actual hackathon. In a hackathon, the experience is more immersive (1 to 3 days), while the time of a class is typically the time taken for ideation of a hackathon project. We also found the case of three-week projects using mobile DNA sequencers, where weekly meetings in the class were being called a hackathon [18].

B. Challenge-Based Learning Framework

The Challenge-based Learning (CBL) framework initially emerged as an approach to foster learning while solving real-world problems [19]. It has a solid foundation on experiential learning and was initially targeted high school students, later evolving to a version [20] more suitable to higher education. The approach has similarities to Problem-based Learning (PBL) [21]. However, instead of merely focusing on a predetermined problem within an action domain, there is an idea of global importance linked to the problem in question (e.g., sustainability, safety, urban mobility), but with local applicability [22]. In CBL, questions are fundamental. Both at the beginning, through an essential question, and during the process of proposing solutions, through guiding questions. CBL divides the activity of learning into 3 phases (Figure 1):

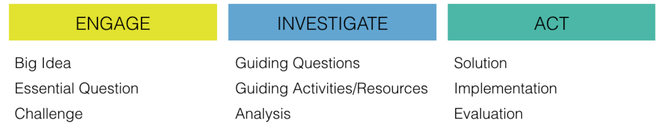

Fig. 1. Phases of the original CBL framework

Engagement. students define and explore a *Big Idea* (e.g., health) that matters to a broader community. It is followed by an *Essential Question* (e.g., what do I need to do to be healthy?) to contextualize and personalize the Big Idea. The last step in this phase is a *Challenge* (e.g., Engage sedentary people to exercise) determining a call to action that leads students to learn more about the subject and develop a solution.

Investigate. is the stage where students and teachers take part in a research journey on topics related to the challenge. It starts with *Guiding Questions* (e.g., what are the typical obstacles for exercising?) that students should make and prioritize to give a direction to their research path toward the necessary knowledge to build a solution for their challenge. The *Guiding Activities* (e.g., Web search, field research, surveys, interviews) and *Guiding Resources* (e.g. online databases and journals, public libraries, experts in the field) are tools to answer the Guiding Questions. The *Analysis* is when Learners present what knowledge they acquired until this stage.

Act. is where the solutions are implemented targeting a real audience. The *Solution* is where the conception takes place through prototypes, experiments, and tests. The *Implementation* consists of putting into practice what was developed. The *Evaluation* concerns the gathering and evaluation of data (analytics, surveys, interviews, questionnaires) about the impact of the solution and if it fulfilled the expectations.

C. Design Thinking

The Design Thinking paradigm shifts from traditional product design to embrace complex problems and focus on consumer experiences and the various possibilities of experience in using the artifact at all stages of its life cycle. The design thinking strategy is a human-centered approach [23]. It establishes the understanding of the users as the source of all insights to solve problems and create appropriate solutions.

It is a process of problem-solving centered on human problems and is divided by IDEO into three spaces: inspiration, ideation, and implementation. Inspiration is the "problem or opportunity that motivates the search for a solution", ideation is the "process of generating, developing, and testing ideas", and implementation *"the path that leads from the project stage into people's lives"* [24]. Brown also describes three essential aspects of an insight or idea that leads to innovation. An idea should be desirable by the user, viable as a product in the market and feasible regarding technology and its possibilities.

III. Proposed Hackathon Methodology

The proposed methodology was adapted from a mobile app development framework used in our institution, that mixes CBL and design thinking. With this adaptation, we intend to motivate hackathon participants to choose an application domain based on their passions but also stimulating them to design products created without any investigation or evidence of user needs. The usage of design thinking aims to enrich the motivational process with ideation and design techniques to feed the entire process with creative and useful ideas.

The arrows in Figure 2 illustrate the adaptations we did to the CBL framework, by embedding design techniques throughout the steps transitions. Users of our methodology can follow it autonomously and use design techniques transparently. The techniques are hidden in the form of guiding questions which are specific to a given CBL phase (e.g., who are your users? what are their preferences?) as well as guiding activities (e.g., perform web searches to gather information about the target domain). It will conduct the groups to execute the pre-defined activities without needing to know details about the techniques behind them. This is possible with little guidance on how to use of the instructional kit that consists of a set of ”card sheets”, such as the one presented in Figure 3, which are bundled in a slide presentation file handled to the hackathon participants. During each step of the project, they fill out each sheet (a presentation slide) to guide them throughout the process. At the end of the process, they will already have automatically documented the decisions they took.

Fig. 2. We place the investigate phase (blue) between adjacent CBL activities

A. *Design Techniques Embedded in the Methodology*

The next subsections briefly overview the design techniques that were embedded in our methodology.

1) Brainwriting: Different factors may influence the adoption of creativity techniques, but cognitive preferences may be an aspect that has to be carefully managed [25]. Because teamwork involves people with different backgrounds, instead of creating opportunities for conflict, teams should move toward equal participation. Brainwriting typically leads to superior idea generation than brainstorming techniques [26] and also gives more opportunities to introverted people to express themselves. This is one of the reasons we chose to embed an adaptation of the 6-3-5 Brainwriting [27] technique in the process. The card sheet from Figure 3 illustrates one of our proposed templates that suggest the usage of brainwriting.

2) Voting Heuristics: One of the challenges in the design thinking strategies is to manage the vast number of ideas and research material produced by an interdisciplinary team and how it all could be transformed into a concrete solution. The phases to achieve this is ruled by ideation techniques as brainstorms or SCAMPER [28]. The generated ideas are presented, filtered and chosen by the three aspects described previously (desirable, viable and feasible) and refined to the phase when they will become a final prototype. Figure 3 presents a card design with four rectangles where team members may enter with different ideas generated with brainwriting. On the bottom of each rectangle, there is a subdivision in three areas, representing each of the three aspects. In our proposed heuristics, the group must arrive at a consensus to give points (ranging from 1 to 5) on each aspect, for each idea. The idea with more points will be selected.

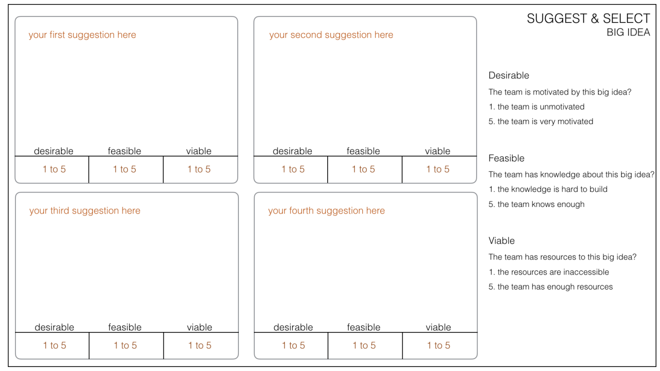

Fig. 3. Cards sheet used for brainwriting

3) Persona: The Persona technique [29] can be useful in projects where there is no stakeholder available to act as the project's client. It consists of an archetype summarizing the needs and habits of user groups representing the product audience. Usually, it is based on data collected from field research that helps to frame the profiles of hypothetical users. The team can use it as a reference, always asking themselves if the product being developed is addressing the persona's needs.

4) Physical Computing Cards: The Physical Computing Cards is a set of 125 cards, which represent common components (sensors, actuators, storage and communication modules) used in physical computing and IoT projects. One of the authors created the deck as classroom material for Design and Computer Science courses. In the classroom context, the main objective is to provide the students with a structured, modular, and playful way of exploring possible combinations of inputs and outputs for physical computing projects. It was inspired by IDEO's method cards [30], Interaction Tarot [31], Design Heuristics [32], Oblique Strategies [33], Creativity Whack Pack [34], and Innovative Whack Pack [35].

The physical and homogeneous way the cards present the information can: (1) influence the reduction between theory and practice; (2) work as an anchor to develop concrete knowledge; (3) function as a *lingua franca* to help the communication between the different collaborators, and (4) can positively impact the idea generation [31]. The colors represent categories of components: red (sensors); blue (actuators); and green (means of communication and storage, such as protocols, components, memory devices). On the front side of each card, an icon and a title visually represent the components. Each card has on its back a QR Code with a URL linking to a wiki explaining the usage of the component.

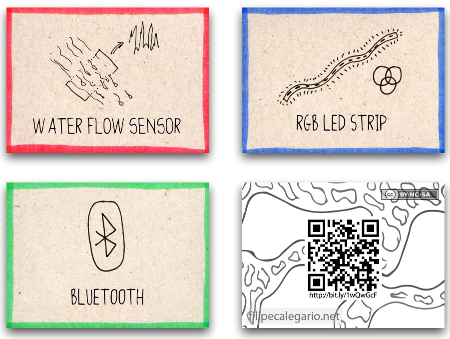

Fig. 4. Examples of the three physical computing cards categories

B. *Methodology Activities*

We took as a theoretical reference the different steps in the user-centered requirements analysis proposed by Maguire and Bevan [36]. Since the hackathons outcomes consist of prototypes, we considered that the generation of such type of artifact is typically employed in software engineering during the requirements phase of a project lifecycle. Maguire and Bevan propose different phases where many ethnographic research techniques (e.g., field study observations, focus groups, interviews, scenarios) are applied. The four phases consist of information gathering; user needs identification; envisioning and evaluation; requirements specification. In that process, prototypes are developed in the envisioning and evaluation phase. In the case of our methodology, the prototype is where our cycle stops. Therefore, requirements specification was left outside our proposal. Similarly, CBL's implementation (i.e., deployment/release in software engineering) and evaluation phases were also left out. Table I draws a parallel with the CBL activities and the selected design techniques.

The time allocation for each of the phases may vary according to the overall time allocated for the hackathon. The project development phase is the one that should consume most of the time. For 48 hours hackathons, if the organizers are interested, this phase can be preceded by an additional phase to explore low-fidelity prototyping before groups start developing the final solution. The work of mentors is fundamental during this phase. The final task of the groups is to do a pitch [37] where they present the steps taken in the process and the solution they developed, followed by a quick demonstration.

IV. Empirical Study

The study we performed focused on the perception of hackathon participants about how the combination of challenge-based learning and design thinking could influence their projects. We attempted to answer the following research question: "What effects can the combination of challenge-based learning and design thinking have on hackathon projects?".

A. *Research Method & Study Setting*

A mixed methods approach was employed, with both quantitative and qualitative data analysis being utilized. The method followed a triangulation design using a convergent model, where qualitative and quantitative data are analyzed separately, and the results converged during interpretation [38].

We applied this methodology in an Internet of Things hackathon, that was conducted within the context of an undergraduate optional semester course that was offered in our university by one of the authors of this paper in the second semester of 2017. We reported another part of this study using different data collected in the same setting, rather focused on learning aspects in hackathons [8]. The current paper is focused on the hackathon methodology itself. The population consisted of 22 students divided into seven groups. These participants were undergraduate students from the Computer Science and Information Systems courses who were enrolled in the *Web of Things* course. The final project of the IoT course would be developed during the hackathon, which was organized under the same format of an authentic hackathon: a non-stop event; an appropriate location for that type of activity; clear goals; mentors to provide support; hardware kit available to participants; clear criteria for selecting the "winners".

The event was held outside the university campus, in a maker space located in the tech innovation hub. Maker spaces are places for creative and technical work, being very significant to support the innovation community and informal learning [39]. That type of infrastructure was more appropriate for a hackathon than the university laboratories. The hardware kit for each group had a Raspberry Pi computer; a set of sensors (e.g., temperature, air quality) and actuators (e.g., servomotor, led); jumper cables and a prototyping circuit board. The hackathon lasted 24 hours (Saturday 13:00 to Sunday 13:00). Teams had 30-45 minutes cycles to work on each of the four initial phases (Table I) of the methodology. It ensured that they would all start the development at the same time and no team would get stuck in lengthy discussions about ideas, as it can often happen during hackathons. Two intermediary checkpoints (one at Saturday night and the other on Sunday morning) were made with the teacher. Pitches started at 12:00 on Sunday. The seven project descriptions are shown in Table II, detailing the first steps of the methodology.

The goal of the hackathon was to get students to develop a connected IoT artifact tackling a real user problem, according to the domain of their preference, so they would have a purpose and more realistic motivation to practice what they learned in the semester. Participants would have to follow the proposed methodology. Students from Computer Engineering who were experienced with IoT prototyping volunteered as mentors. Just like the majority of hackathons, there was a jury in this one, composed by the teacher and mentors. The idea was selecting the three best projects. There were explicit criteria for ranking the projects: technical complexity; potential

TABLE I
PROPOSED PHASES IN OUR HACKATHON METHODOLOGY

Requirements Phase	Design techniques	CBL phase (outputs)	General Goal
Domain definition	Brainwriting and heuristics	Big Idea	Choice of a domain of interest
Information Gathering	Brainwriting and heuristics	Essential Question	First round of investigation on the chosen domain to look for relevant problems
User needs identification	Brainwriting, heuristics and Persona	Challenge	Second round of investigation for identifying stakeholders needs, potential users and the challenge they need to overcome
Envisioning and evaluation	Card prototyping	Solution (concept)	Presentation of the application concept that will tackle the identified challenge
Project Development	–	Solution (working prototype)	Presentation of the fully functional prototype to the audience and evaluation round by mentors

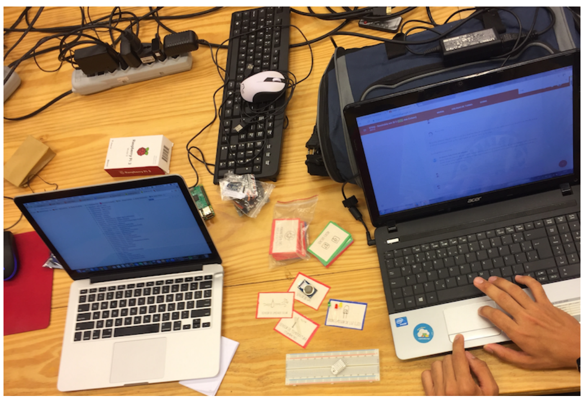

Fig. 5. Physical computing cards used for IoT prototyping in the hackathon.

impact for society; visual appeal; and quality of presentation. However, the project grades for the course would not be based on that ranking which worked more as a resource to bring more authenticity to the event. A team of 6 mentors was available to help the students and to participate as evaluators.

B. Data Collection & Analysis

For this study, we collected data from hackathon participants through two types of instruments: survey (quantitative data) and group interviews (qualitative data). On the week after the event, online questionnaires were sent by email to students, and group interviews were performed face-to-face. The former mostly consisted of questions using a five-point Likert scale response format. The latter consisted of semi-structured interviews with separate groups of students: those with previous CBL experience and those without. The questionnaire data analysis used Spearman's rank correlation coefficient. One of the researchers performed the interviews, recorded and later transcribed then two researchers codified them. The first cycle consisted of coding process where a generic coding method was applied followed by a second cycle where the number of codes was condensed, and codes categorized [40].

Questionnaire. The questionnaire used in the survey aimed at getting quantitative data about the participants' perception of the hackathon methodology and the effectiveness of the different design thinking techniques that were used. It consisted of 2 background questions and 12 questions with a Likert-scale response format (Fig. 6) about the methodology. The background questions were about previous experience in hackathons and with hardware prototyping before the course.

Interview. The interview was performed after the hackathon, with questions aiming to understand the participant's perception of the methodology and the different design thinking techniques it applied. The first two questions were directed to those who had already participated in hackathons and who had previous contact with the CBL methodology, respectively: How did the methodology differ from other hackathons? How did the methodology differ from the typical CBL practice you had? How did the methodology help to narrow down the scope? How was it helpful to research/seek for domain knowledge and users/stakeholders? What did you think about using the solution prototyping with the cards? How did the brainwriting and the heuristics help? What was your perception of the utility of this methodology for hackathons?

Ethics. Although this approach may raise ethical controversy; each student signed an Informed Consent Form. The form detailed the objectives of the study, guaranteeing the confidentiality of the collected data and anonymity of the participants. It also mentioned they could leave the event at any time without any penalties.

V. RESULTS

All 22 participants answered the questionnaire, whose answers are summarized in Table 6. The majority (14 students) was participating in a hackathon for the first time. Only 3 participants had experience with hardware prototyping in a project from scratch, while 4 had done just some examples. The remaining 15 had no previous experience on that. The group interviews had 8 participants divided into two subgroups: 3 students that had prior contact with classes using CBL and five students new to CBL concepts (see Table III).

TABLE II
OUTPUTS OF THE IDEATION PROCESS FRAMED BY CHALLENGE-BASED LEARNING CONCEPTS

Group#	Big Idea	Essential Question	Challenge
1	Travelling	How to be sure no one has taken my luggage by mistake?	Ensure that the passenger does not leave with the wrong bag from the airport.
2	Agriculture	How to grow quality vegetables in a domestic environment	Make possible the cultivation of organic vegetables without human supervision
3	Home automation	How to make life easier for beverage lovers?	An iot solution to manage the time your drink should cool down so you can enjoy the best taste
4	Agribusiness	How to predict and identify possible sources of fire in private rural estates?	Assist in the prevention and identification of fires on private rural properties.
5	Fin tech	How do you enable a person to leave the house with as few belongings as possible and allow them to spend their money in a practical way?	There is always something that a person needs to take to the street. It should make the user feel no need to take anything other than their tag (RFID/NFC) when leaving home.
6	Healthcare+Wearables	How to help people with motor coordination problems in therapy process	Assist patients' activities by helping the patient to correct his movements?
7	Electricity	How to prevent people from having an electric shock at home?	N/A

TABLE III
STUDENTS PARTICIPATING IN THE INTERVIEW

Student	S1	S2	S3	S4	S5	S6	S7	S8
Group	1	2	3	2	4	6	5	7
CBL Experience	Y	Y	Y	N	N	N	N	N

A. Quantitative Data

The survey answers presented in Table 6 show that most of the questions (Q1, Q2, Q5, Q6, Q7, Q11, Q12) had a prevalence on the majority of the answers tending to be positive (somewhat agree or strongly agree). For instance, when participants were asked if the methodology was fundamental to define the project (Q1), there was only one neutral response while all the rest agreed it was important.

Questions Q3, Q4 (both about the use of design thinking techniques), Q8 and Q10 (also about a creativity technique) were the ones with the smaller proportion of positive responses. Concerning the brainwriting method in each step of the methodology (Q3), a significant part of the survey respondents (32%) informed not following the brainwriting, while more than half (54%) reported they followed it.

However, when looking at Table IV, where we can see the correlation of the responses, there is a strong positive correlation between Q3 and Q4 (ρ= .548, p<.01). It suggests that those who followed brainwriting also followed the heuristics. For Q2 and its strong positive correlation with Q5 (ρ= .723, p<.01), Q6 (ρ= .424, p<.05), it suggests that following the steps proposed in the methodology may help to generate ideas and to converge them, respectively. This is reinforced by the correlations between Q6 and Q3 (ρ= .495, p<.05), Q6 and Q4 (ρ= .690, p<.01), as well as Q6 and Q5(ρ= .565, p<.05).

B. Qualitative Data

After the interviews, it was possible to verify the students' perception of using the methodology and the underlying design techniques that were used. One of the most commented aspects concerned the category of time optimization, which appeared many times in the form of various codes (e.g., quickness, low usage of time). Some quotes[1] from students concerning time can be found below:

> *"Using CBL was good because it saved time by guiding the idea (...) We did not waste so much time ideating."* (S3)
>
> *"In other hackathons, the idea was based on someone's idea. There was no focus, and we always had about two or three hours to get an initial idea."* (S6)
>
> *"if we were to do without the methodology, it would take us a lot longer."* (S7)
>
> *"For a person who does not have a script in mind or how the development of a solution works, it is fine ..., it is effective"* (S8)

Some groups did not exactly follow the methodology as it was proposed, mainly due to time constraints. The category of methodology adaptation emerged from similar codes such as process adaptation and methodology adaptation. Even though the process could have been seen as constraining, some students saw it as something flexible (quotation from S2) and naturally adapted the methodology, however arriving quickly at results (quotation from S4):

> *"It gave us much more choices, it left us much more free than a normal hackathon, which leaves you locked down in one thing."* (S2)
>
> *"Each member had to make one (card) but everyone made it together and in theory was fast."* (S4)

Techniques such as the physical cards were presented without much detailed explanation, leaving the students to figure out their own ways to use it. It was intuitive in some cases (quotes from S3 and S5) but for other (quote from S8) leading to quit using it:

> *"It showed all the possibilities of sensors that we had. (...) And it's easy to understand that"* (S1)

[1] All quotes were translated from portuguese

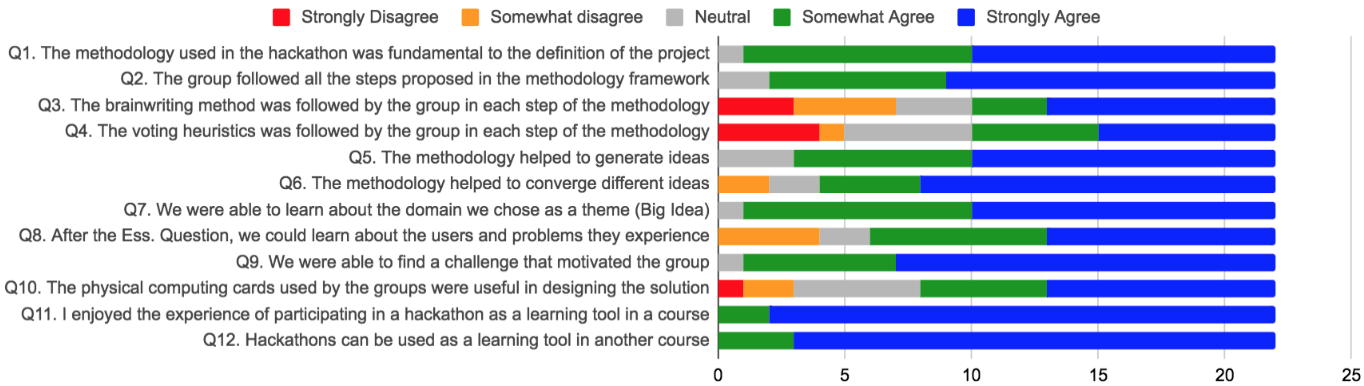

Fig. 6. Visualization of the Likert-scale responses with values ranging from 1 (Strongly disagree) to 5 (Strongly agree)

TABLE IV
SPEARMAN'S ρ CORRELATION OF THE QUESTIONNAIRE RESPONSES

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Q1	1											
Q2	.415	1										
Q3	.078	.346	1									
Q4	.162	.241	.548**	1								
Q5	.488*	.723**	.190	.261	1							
Q6	.159	.424*	.495*	.690**	.565**	1						
Q7	.333	.415	.389	.433*	.488*	.477*	1					
Q8	.105	.156	-.041	.413	.195	.560**	.105	1				
Q9	.137	.244	.160	.704**	.365	.647**	.411	.408	1			
Q10	.165	.088	.501*	.412	.281	.200	.165	-.249	.198	1		
Q11	.271	.481*	.422	.100	.180	.440*	.271	.273	.076	-.171	1	
Q12	.113	.302	.221	-.059	.042	.283	.34	.223	.212	-.271	.796**	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

> *"We decided to do this in the middle of the process. He even added new sensors because of the cards."* (S5)

> *"We saw that we were wasting time using that thing."* (S8)

The learning aspect was also recurrent in the codes. In different phases of the methodology learning experiences were reported, such as the ones from students concerning the domain analysis:

> *"We did not know anything about the gardens, this plantation business, and we ended up learning a lot. (...) And we learned things from planting and everything (...)"* (S2)

> *"It helped us because we arrived with our big idea very fast. Then he had more time to study. I think it helped a lot in that."* (S6)

Although there are difficulties to actually get participants to contact real potential users, the persona exercise helped them visualize the system with a user perspective:

> *"It did help. Especially in the persona. We saw that, for each type of persona we created, the application was different.'* (S8)

> *"But the process of trying to write the problem to a person helped us to better understand what we were going to do."* (S7)

VI. Discussion

With data collected both from a questionnaire and from interviews we confronted the quantitative and qualitative data. Responses for Q1 presented a strong general agreement on the methodology being fundamental for the definition of the project. It was confirmed in the interviews, where participants emphasized the importance of having time constraints for delivering the outputs. Experienced hackathon participants that without a methodology they would last much longer to define their project ideas. Q2 asked about the steps of the methodology being followed by the groups. Two neutral responses and all the rest of the respondents agreed with that.

The trend on disagreement found in Q3 and Q4 was also in the group interview. It was possible to confirm that one of the groups instead of performing brainwriting, they did a sort of brainstorming where one of the members was responsible for writing down the ideas being generated. Other two groups confirmed they did not follow precisely the brainwriting as it was proposed, while the other three groups did. Among these three groups, two of them had students experienced with CBL-oriented methodologies. It indicates that previous contact with a similar methodology may have facilitated the adoption of the proposed methodology. The responses of Q4, about the usage voting heuristics, had a response pattern similar to Q3. The analysis indicates a correlation between the two, so either a student used both, or they did not use them. Many participants complained about the short time to do the research, brainwriting, and voting, with some of them ”hacking” the suggested voting process to make it quicker.

In the case of the 18% voting partial disagreement and 9% voting neutral in Q8, which was related to better understanding user requirements, the interview could reinforce that negative perception especially due to the fact of limited time to do that sort of research. One of the students suggested that possible stakeholders being present in the hackathon would help participants actually validating the requirements they identified. In Q10 (physical computing cards usage), if the five neutral and the three disagreement responses are summed up, that number comes close to the total number of participants from groups that did not use those cards. In the interview, two groups informed they did not use the physical computing cards, representing seven students who are roughly the same number of neutral (5) and disagreement (3) responses for Q10.

A. *Methodology usage*

Many of the groups ”hacked” the proposed methodology to better suit them. Group 4 did not use the cards in their initial discussion, but during development, they decided to do improvements on the project and then started using the cards, which influenced their decision to include a new type of sensor.

Table V details which design techniques were used. Only the persona technique was used by all of the groups, while others were not used or partially used by some groups. Groups having students with previous experience in CBL techniques had better coverage of methods used in the hackathon. Although physical computing cards were new to all groups, it was the second most used technique.

TABLE V
USAGE (YES, NO, PARTIAL) OF THE MAIN DESIGN TECHNIQUES PER GROUP.

Technique	**G1***	**G2***	**G3***	**G4**	**G5**	**G6**	**G7**
Brainwriting	Y	N	Y	N	Y	P	N
Persona	Y	Y	Y	Y	Y	Y	Y
Voting heuristic	Y	Y	Y	P	N	N	N
Cards	Y	N	Y	Y	Y	Y	N

*Group having at least one student with previous CBL experience.

B. *Bias in project ideas*

The sensors and actuators available for each group introduced bias in some groups since the beginning of their ideation process. This bias was more apparent in the Fintech group, which in part chose that domain due to their interest in using a fingerprint sensor that was available. After noticing that a jumper cable was missing, they pivoted their solution to use NFC (Near-field communication - a sort of RFID technology).

Another case of idea bias was in Group 7, which focused on electricity. Although during the interview one of its members claimed that the group arrived fresh without anything specific in mind, they also claimed they did not follow the brainwriting technique. The domain choice seemed to be influenced by the group member who was an intern in the local electric company and motivated the group to choose that context. Among the proposed techniques in the methodology, only the persona technique was followed by that group.

C. *Limitations*

Among the limitations of the approach, we consider the hackathon format to be limited to project-oriented courses, not being feasible for theoretical courses. Another limitation on this study is that it has data of only one group of students. More data would have to be collected throughout other semesters to compare results. The modest size of the group, with 22 students, also may be a limiting aspect. This may affect claims, especially in the quantitative results. Also, the power and authority dynamic between teacher and students could have influenced their responses to be biased and affirmative to the teacher’s approach. To minimize that, students were informed that responses were anonymous and would not affect their grades. We explicitly asked them to show criticism in order to improve the methodology. Negative and neutral feedback was found in the interviews, thus providing evidence of an affirmative bias being minimized.

VII. CONCLUSIONS AND FUTURE WORK

In this paper, we combine challenge-based learning and design thinking to propose a methodology focusing on the usage of hackathons in undergraduate courses. We conducted a quantitative and qualitative analysis to evaluate the usage of the methodology in an IoT undergraduate course. The overall feedback in the quantitative analysis shows an agreement about its effectiveness. We could also observe that the interviews’ answers confirm that one of the main effects of this methodology is that the strict time for intermediate deliveries in each step of the process helped to narrow down ideas and quickly find solutions to be developed. The usage of CBL helped to guide students and give a purpose to their projects, at the same time that it guided them to learn more about the target domain and potential users. Not all of the groups correctly applied the design techniques but were helped by that to some extent. Although this hackathon methodology was applied to a classroom within the context of an undergraduate course, we believe it applies to other courses as well as other hackathons out of the educational scope. Based on the experience of one of the authors, the classroom hackathon followed the typical structure of an authentic one. Participants who had previous experience in that confirmed the authenticity of our setting.

As future work, we intend to apply this methodology to other groups and compare the data collected in various semesters. We plan to do that in the context of undergraduate courses as well as in general purpose hackathons to provide a comparison with a non-academic context.

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