Impact of the Use of Collaborative Learning Networks in Programming Education within a Challenge-Based Learning Approach

Rodrigo Adamski
Center of Informatics
Federal University of Pernambuco (UFPE)
Recife, Brazil
rap3@cin.ufpe.br

Cristiano Araújo
Center of Informatics
Federal University of Pernambuco (UFPE)
Recife, Brazil
cca2@cin.ufpe.br

***Abstract*—This research-to-practice full paper describes the results of using Collaborative Learning Networks (CLN) in an undergraduate iOS development course based on the Challenge Based Learning (CBL) framework. The results show the value of these networks as an alternative source of support for students who become stuck learning difficult content, particularly in environments where student autonomy is encouraged. In the scenario under investigation, students enjoy a certain independence in choosing their own learning goals and taking responsibility for how to conduct their learning journey. Since their learning demands and difficulties are shared but unknown among students with little involvement, a case study was proposed to group undergraduate students with similar learning demands through learning networks. Networked students were encouraged to collaborate through dynamics. 68% of participants reported reaching out to network peers to collaborate at least once and experienced a moderately positive improvement in completing their learning objectives compared to non-networked students. High levels of student networking satisfaction were also observed.**

***Index Terms*—Challenge Based Learning, autonomy, Collaborative Networked Learning, Networked Learning, teaching programming, active methodologies, Collaborative Learning**

I. Introduction

Learning to program can be particularly challenging since, besides the content involving new paradigms for students, part of the learning can be considered very abstract and little related to real situations [1]. Consequently, some active methodologies emerge with their eyes focused on forming a profile suitable for the so-called skills of the 21st century. One example is Challenge Based Learning (CBL), which focuses on finding solutions developed collaboratively for real problems from different aspects, such as in environmental, health, and social contexts.

A clear contribution of frameworks such as CBL is to enable learners to realize their purpose in the learning process, which has been shown to promote positive effects on academic performance [2]. This encourages students to play a leadership role as primary researchers in their journey and removes the mentor's role as the main source of knowledge to complete the proposed activities, becoming the facilitator of the learning process [3].

An inherent part of CBL is that learning becomes a collaborative experience; therefore, there is a great tendency for programs that adopt it to encourage team building [4]. The iOS Developer Training Program is an example of an environment that adopts this framework. In this hands-on program for developing mobile applications, learning is collaborative, combining the autonomy of each student in their choices (what to learn, which topics to prioritize, with whom and how to learn) and the common demands of their group, which works towards a solution to the challenge presented within the CBL cycle.

Two obstacles arise, the first concerns students with a consumer profile, who may remain inactive in a context different from the knowledge-centralizing culture [5], thus struggling with autonomy in content not covered by mentors, especially those who have never had prior contact with programming. The other obstacle is related to the compatibility between the demands of the individuals in the group since each student can use their learning choices in different ways to solve the shared challenge. However, sometimes they may not find alignment with other colleagues in their team, tending towards a more solitary learning journey.

These difficulties are often visible among several program classes, where challenges and demands are shared among individuals from different teams. However, there is typically little awareness of colleagues from other teams who might have greater compatibility. In the development of a mobile application, for example, students must go through several stages such as creating a layout, user experience testing, front-end and back-end programming, and databases, among others. Fig. 1 illustrates the case of two students from different groups interested in delving deeper into front-end development, while the other group members focused on other areas. Without the necessary mechanisms, these students often took the course restricted to the social circle of their group, missing out on some of the benefits of connecting their learning with peers with common learning interests.

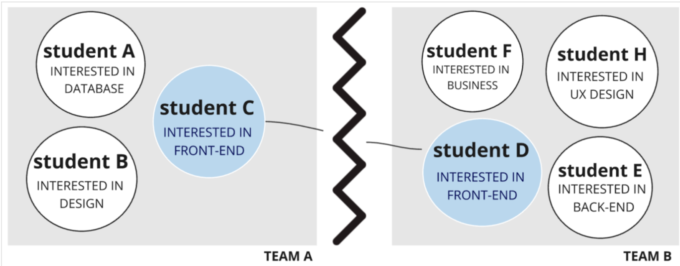


Fig. 1. Students with similar needs are unaware of each other's needs.

One solution to address this issue is through Collaborative Learning Networks. In CLNs, students are temporarily grouped based on specific and momentary demands. This allows them to learn collaboratively and provide a common response to challenges that affect their learning on specific topics they are most interested in exploring, which may not be usually addressed within their traditional class teams.

The main objective of this research, therefore, is to present the results of a case study that uses such networks within a CBL methodology. To this end, emphasis was placed on the stages of identification, grouping, and stimulation of collaboration of students with similar demands. Furthermore, it aims to understand the effects that an alternative source of student support has in the learning process of mobile application development.

This paper is structured as follows: Section II provides the fundamental background used in this paper, including related work and the research questions raised. Section III presents the methodology, the algorithm used to group the networks, and the parameters to feed the algorithm. Section IV presents the results based on the research questions. Section V brings the discussion and the contribution to the literature. Finally, section VI concludes the paper.

II. Background

A. Challenge Based Learning

The Challenge based Learning (CBL) framework originally emerged in the high school context as an approach to promoting learning by solving real-world problems [6]. Later, it evolved into another version tailored for higher education. CBL asserts that when students learn by solving such complex and pressing problems, it results in deep, meaningful, and intentional learning activities in a practical and collaborative way [7].

This framework is structured into a 3-phase cycle: Engagement, Investigate, and Act. **Engagement** - students explore a Big Idea (e.g., environment), often an abstract concept. Then, a question is asked to reinforce the Essential Question (for example, "How do floods affect cities?"). Finally, there is the Challenge, which centralizes the entire cycle (for example, alerting city residents in time about possible floods) and demands action [8]. In **Investigate**, students and instructors participate in a research journey on topics related to the challenge. It starts with Guiding Questions (for example, "How are river levels measured?"), and students investigate ways to answer them. **Act** is the phase in which solutions are effectively implemented, targeting a real audience and implementing the solution. At this stage, crucial to this research, students apply what they have learned and face the challenges of translating theoretical knowledge into practical solutions.

B. iOS Developer Training Program

The iOS Developer Training Program is part of an innovation education initiative. It aims to shape the profile of graduate students to go beyond the technical area, emphasizing soft skills such as creativity, communication, and critical thinking, while also practicing topics related to programming, design, and business.

The initiative consists of two modalities of face-to-face classes exclusively for undergraduate students. The long-term version spans two years, covering several CBL Challenges. The shorter modality lasts one academic semester, focusing on a single Challenge and counting as a regular course of the institution.

The CBL adopted by the Program has some particularities. One of them is linked to the final product of the Challenge, the development of an iOS application by each team presented to the project's beneficiary Stakeholders. Another particularity is related to the knowledge necessary for product development, which is organized based on learning goals and learning objectives (LOs) sourced from three areas [9]:

- What they want to learn (exclusive to the long-term modality);
- The content proposed by the Program;
- Requirements or particularities related to the current CBL Challenge.

In the semester under investigation, the theme for the short-term modality was 'Impacting the Developer Program Community.' As a result, teams presented solutions such as applications for learning management, organizing extracurricular events, and creating a repository for storing tasks. While these solutions shared basic learning objectives, each also exhibited particularities in its development.

C. Collaborative Learning Networks

CLN, often referred to as Networked Collaborative Learning (NCL) or even Networked Learning (NL), shares characteristics with Communities of Practice, where individuals with a shared interest in a specific topic or domain come together to deepen their educational, professional, or personal knowledge. Learning about this area of interest is the explicit intention of all individuals within a learning network. NCL is seen as an artifact that can be designed to promote interaction among its participants in the learning process. Theorists summarized eight principles that support network learning programs [11]:

- The focus is on learning that has a perceived value for students;
- Responsibility for the learning process must be shared among all participants in the network;
- Allow time to build relationships;

- Learning is situated and context-dependent;
- Learning is supported by collaborative or group environments;
- Dialogue and social interaction support the co-construction of knowledge, identity, and learning;
- Critical reflexivity is an important part of the learning process and knowing;
- The role of the facilitator/animator is important in networked learning.

Networked learning is, therefore, positioned as a non-formal learning process (intentional learning that goes beyond normal class settings) or informal ("accidental", unintentional learning that happens in conjunction with the use of other activities) [12][13].

In this way, within the context of the researched program, networks take on a non-formal learning role. They are exclusively focused on learning topics of interest, not having the responsibility for developing a product -in this case, an application- which differentiates them from the traditional group.

D. Related Work

This scenario seems to be relatively unknown and little explored in the context of interdisciplinary computing education, particularly within CBL environments. Among the few related initiatives, NL has been implemented alongside Problem-based Learning (PBL) methodology in some studies [14][15] that offer a conceptual-level approach to how both complement each other.

These studies reinforce that while NL was exclusively concerned with issues of connection between actors, via computer or not, PBL was willing to formulate problems and investigate exemplary problems (anomalies), participant control, interdisciplinarity, joint collaborative projects, and learning through action [16]. Similar to what occurs in PBL, during CBL cycles there is an immersion focused on producing artifacts related to the proposed challenges. However, because knowledge production is in a constant state of flux, students may subsequently realize that although they have focused on their project, important knowledge within their reach has not been integrated [16].

In the context of programming education, studies related to NL have focused efforts on how to structure collaborative tools for NL. In particular, these studies suggest visual resources and design solutions that focus on the objects of discussion, and through these discussions, students understand and build on each other's work and thus engage in knowledge-construction processes [20].

E. Research Questions

The guiding research questions for this study were developed following the previously mentioned main objective. The research questions are:

RQ1: To what extent do students engage with the proposed network for learning?

RQ2: How do these networks help students in overcoming learning obstacles?

RQ3: Do networked students exhibit increased autonomy from mentors?

RQ4: How does peer networking, as facilitated by this research, enhance the learning experience?

III. Methodology

A. Participants and Context

A total of 17 students from the short-term modality of the iOS Developer Training Program were allocated and assisted in networks during an experiment that lasted a total of seven weeks (five weeks of applying collaborative tasks and two weeks of analysis and preparation of participants) during the Act phase of the CBL.

Initially, students filled out a form indicating their learning interests among the LOs available for that Challenge. Subsequently, they provided information about their preferences in music, movies, hobbies, and sports. This latter information contributed to a relevant parameter for grouping students with more similar profiles [17].

After processing the data, participants were grouped into four networks using a clustering algorithm (K-medoids), with three networks containing four members and one containing five members. Subsequently, students were introduced to each other.

B. Proposed interaction

Throughout the experiment, participants engaged in interactive dynamics designed to encourage interaction and collaboration within their networks. These dynamics, occurring one to two times a week, consisted of small tasks to break the ice, reenergize, or learn concepts discussed in the room. Promoting interaction was crucial since just grouping students may not be enough for them to start effectively collaborating [18].

Once grouped, network members were introduced to a Kanban tool used to visualize LOs and their shared preferences. In the same tool, the dynamics were posted on a digital board, where students could respond, contribute to their peers' answers, and ask questions on relevant topics related to their LOs.

Since the goal of the dynamics was to promote social interaction and keep the network active, the dynamics mixed relaxed and learning themes with a focus on common interests. The icebreaker dynamics encouraged students to share interesting facts during the initial networking handshake, reducing the lack of intimacy. Next, and predominantly, learning dynamics were presented, such as *"Explain to your network colleagues a piece of code you wrote but use only metaphors"* and *"Invite a colleague from the network to discover coding best practices related to this goal"*. Finally, energizer dynamics were responsible for boosting students when collaboration was decreasing. This decrease was measured by a low interaction rate in the learning dynamics and low progress in the evolution of LOs completion. Energizers consisted of notifications such as *"We are missing you in the OA study. Would you have 5 minutes to study with your network colleague?"*.

C. Data collection

Participants were monitored through their participation in the dynamics and during weekly meetings, in which they were asked whether they had studied in collaboration with any network colleague that week. A Learning Support Tool, developed to assist the journey of students and mentors during the course, was responsible for periodically tracking the completion of the learning objectives.

At the conclusion, quantitative data were gathered from a questionnaire consisting of 30 Likert-scale questions. These questions covered dimensions related to collaboration, learning, mentor autonomy, networking, and perception of the experiment, with response options ranging from 'Totally Disagree' to 'Totally Agree'. Additionally, a qualitative approach was employed through interviews to complement and reinforce the understanding of the quantitative data.

IV. Results

A. Collaboration in Networked Learning

RQ01: To what extent do students engage with the proposed network for learning?

The average values from Fig. 2 indicate a strong inclination towards collaboration within the network, as all responses are at least or above 73% agreement. Specifically, when asked about helping or seeking help from a colleague in the network, over 66% of students reported doing so. These findings suggest that students actively utilized the network for collaborative purposes, not only when facing challenges but also when seeking to explore new knowledge alongside their peers within the network.

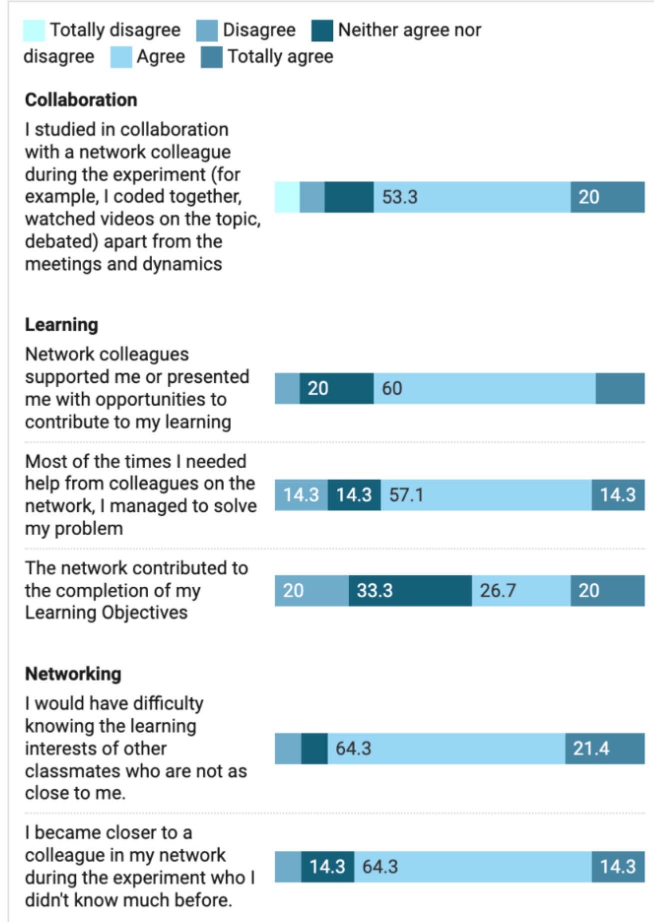


Fig. 2. Partial results of the self-assessment survey on network use.

The data collected during weekly meetings monitored whether students reported spontaneously reaching out to a member of their NL to study collaboratively. Fig. 3 illustrates the variation in the percentage of collaboration declared by students over five consecutive weeks. A general tendency for the percentage of collaboration declared to increase over the weeks was observed, starting at 52% during the initial week and gradually rising to 70% by week 5 as the project deadline approached. This increase can be attributed to the greater need for support to assist with possible difficulties in designing the application. As the project deadline draws closer, the complexity of the features to be coded increased, leading to a heightened demand for collaborative efforts.

Participation in the dynamics, however, proved to have little effect on stimulating the search for peers in the network to study collaboratively. Data from the student participation in the network (Fig. 4) show the percentage of participation per student in the dynamics proposed to the network and how many meetings were attended. The column on the right informs the self-declared collaboration of each participant. When the variables were crossed, a weak positive correlation was observed (Pearson 0.294) between participation in the dynamics and declared weekly collaboration. Subsequent interviews point to an explanation for this value, potentially explaining it as a result of the students' time constraints to develop the final application. Within their networks, students may have prioritized seeking help to meet the demands related to the final product, having less time to complete the collaborative dynamics.

B. Effective learning

RQ02: How do these networks help students in overcoming learning obstacles?

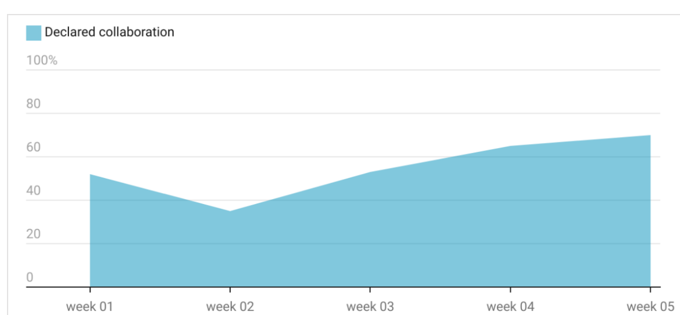
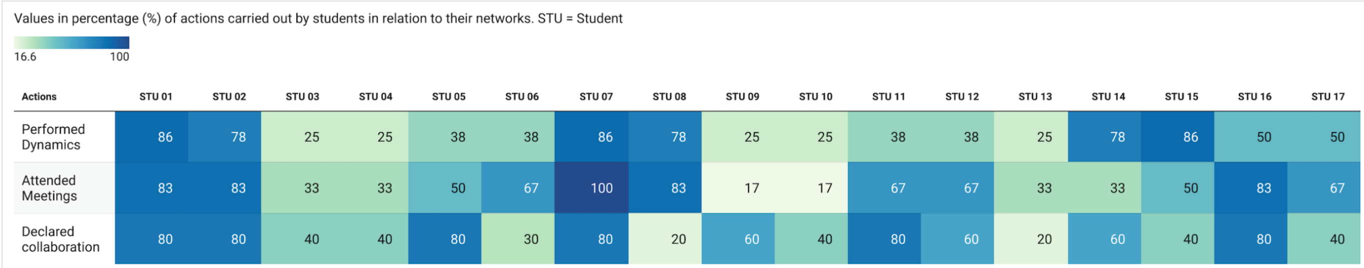


Fig. 3. Evolution of weekly collaboration declared by networked members.



Values in percentage (%) of actions carried out by students in relation to their networks. STU = Student

16.6 100

Actions	STU 01	STU 02	STU 03	STU 04	STU 05	STU 06	STU 07	STU 08	STU 09	STU 10	STU 11	STU 12	STU 13	STU 14	STU 15	STU 16	STU 17
Performed Dynamics	86	78	25	25	38	38	86	78	25	25	38	38	25	78	86	50	50
Attended Meetings	83	83	33	33	50	67	100	83	17	17	67	67	33	33	50	83	67
Declared collaboration	80	80	40	40	80	30	80	20	60	40	80	60	20	60	40	80	40

Fig. 4. Student participation in the network.

Similar results were observed in the learning dimension, as indicated in Fig. 2. The majority of interviewees (71.4%) agree or fully agree that peers in the network supported them or presented opportunities to contribute to learning, and that they managed to solve their problems with the help obtained. Comparisons made between students in a learning network and students without a network demonstrate a 22% lower rate of Learning Objectives completed by non-networked students (networked = 17 / without network = 14) (Fig. 5).

However, it is noteworthy that the perception of the network's influence on the conclusion of Learning Objectives does not appear to be significant, with a significant proportion (53.3%) expressing neutrality or disagreement with this statement.

More information about this difference in data can be obtained from interview feedback. For example, student 06 noted, *'While I was heavily focused on tasks related to application development, I found it challenging to prioritize completing Learning Objectives.'* Student 14 mentioned, *'I often relied on interactions within the network to address immediate application development challenges, perhaps this could have impacted them (Learning Objectives) later.'* These citations highlight the potential indirect influence of students' focus on application development tasks when completing their Learning Objectives, as they prioritized application deployments.

When the collaboration variables declared by students are correlated with the evolution of Learning Objectives during the same period, we observe a moderate positive correlation of 0.596 on the Pearson scale between the variables (Fig. 6). This suggests that, in general, there is a slight upward trend in Learning Objectives as the level of collaboration increases within the network.

C. Mentor autonomy and preference for the network

RQ03: Do networked students exhibit increased autonomy from mentors?

When asked about their main sources of assistance, students primarily sought help from mentors, followed by group mates, and then networks, ranking ahead of other sources such as classmates and members of other groups in the developer program. The quotes below provide insight into the reasons for students' prioritization of mentors and the barriers encountered in maintaining them as their main source of consultation instead of prioritizing network colleagues:

> *'I ended up focusing on working more with those who were physically close to me, whether it was the mentor or a colleague'* (student 09). *'At first, I was embarrassed to talk to colleagues in the network that I didn't know very well, but as the activities progressed I felt more confident talking to them* (student 03)'.

D. Networking

RQ04: How does peer networking, as facilitated by this research, enhance the learning experience?

The results indicate that the majority of participants (64.3%) agree that they often have difficulty knowing the learning interests of less close colleagues. A large proportion of participants (78.6%) agree that they became closer to a colleague

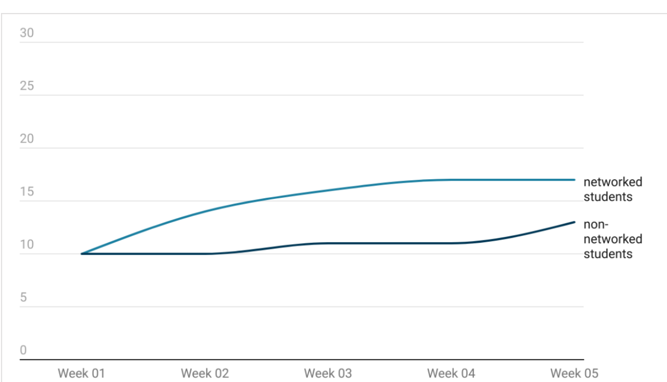


Fig. 5. Evolution of Learning Objectives.

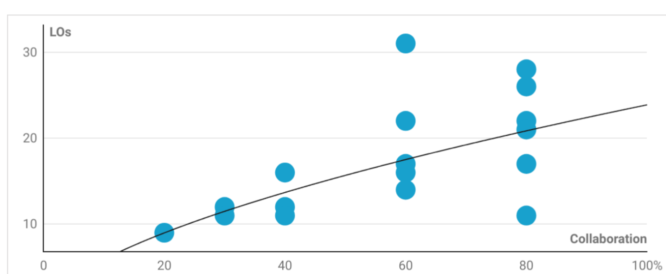


Fig. 6. Evolution of Learning Objectives concluded and declared collaboration by week.

in the network during the course, even though before they did not know them well. This indicates that the method may have facilitated the establishment of connections between participants who were not initially close.

Furthermore, 43.8% agreed that getting to know colleagues better through the network and dynamics enabled faster interaction for learning. This suggests that activities such as icebreakers or collaborative learning dynamics effectively facilitated interaction and learning among participants."

E. Networking Perception

The instrument used to evaluate the perception of networking, as presented in Fig. 7 [19], suggests a generally positive perception regarding interaction and collaboration within the CLN. Participants reported feeling comfortable building relationships and perceived mutual support in learning. However, not everyone noticed a significant improvement in confidence to expand their network, indicating potential variation in the effectiveness of the program across different aspects for different participants.

V. Discussion

The main objective of this article was to examine the use of Networked Learning as a complementary approach to the benefits that frameworks such as CBL bring to developer training. The results of the study add a new perspective to the literature since we are unaware of any study that relates both approaches to date. Even so, similarities with other educational approaches can be observed, in which students are fully involved in a process of developing a real artifact, and this objective can overlap with individuals' learning desires.

Therefore, the findings suggest that grouping students into networks and making them aware of what other peers are working along and their common learning demands may be enough to promote collaboration. For that reason, making them aware that this connection can help reduce barriers in initial collaboration and throughout the learning journey, especially in environments where students have little intimacy with peers outside their social circle.

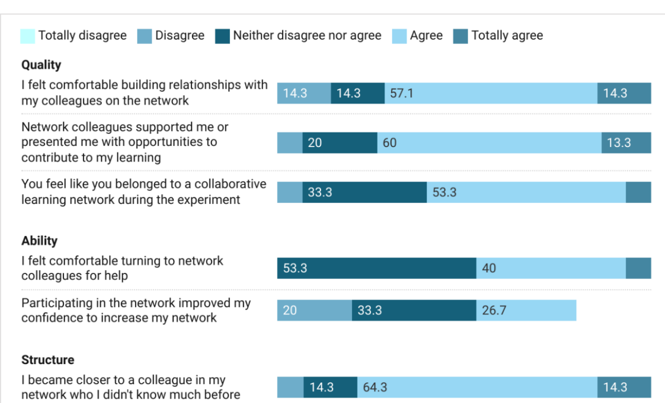


Fig. 7. Students' perception of networking.

Additionally, unlike other related studies, the need for continuous stimulation for interaction through dynamics did not bring the expected effect in this study, since they were not shown to be essential for improving declared collaboration over time [18].

VI. Conclusions, Limitations, and next steps

The results of alternative and collaborative learning support through Networked Learning indicate a moderate positive contribution to completing learning objectives. In other measures, the data also show that students perceive increased networking, especially with peers who would not have collaborated otherwise. This reinforces the network as an intersection of knowledge formed by shared demands of members of different teams, who often, despite similarities, spend an entire course without proximity.

On the other hand, the networks did not have the expected effect on the mentors' independence, as they remained, alongside the traditional group consultation, as the main sources of support for the students. This can be attributed to the students' need to solve problems promptly and the absence of a collaborative tool during the experiment. One limitation of this study is the relatively small sample size of 17 students involved, which we intend to expand by mixing mobile development students from different classes. In addition, the role of the mentor within these networks as a facilitator should also be evaluated in the next steps.

References

[1] M. Dağyar and M. Demirel, "Effects of Problem-Based Learning on Academic Achievement: A Meta-Analysis Study," TED Egitim ve Bilim. vol. 40, ed. 181, 2015.

[2] T. Kelley, J. G. Knowles, J. Han, and E. Sung, "Creating a 21st century skills survey instrument for high school students," American Journal of Educational Research. Vol. 7, No. 8, 2019, pp 583-590.

[3] S. Gómez Puente, and K. Doulougeri, "Challenge-based learning curriculum development: a suitable framework for engineering education," Towards a new future in engineering education, new scenarios that European alliances of tech universities open up. Universitat Politècnica de Catalunya, 2022. p. 1196-1205.

[4] C. Mesutoglu, D. Bayram-Jacobs, J. Vennix, A. Limburg, and B Pepin, "Exploring multidisciplinary teamwork of applied physics and engineering students in a challenge-based learning course," Research in Science and Technological Education, 2022.

[5] M. Hendrickx, A. Schüler-Meyer, and C. Verhoosel, "The intended and unintended impacts on student ownership when realising CBL in mechanical engineering," European Journal of Engineering Education, 48(2), pp. 340–357, 2023.

[6] M. Nichols and K. Cator, "Challenge Based Learning White Paper," Apple Inc.: Cuppertino, CA, USA, 2008.

[7] K.Doulougeri, J. D. Vermunt, G. Bombaerts, and M. Bots, "Challenge-based learning implementation in engineering education: A systematic literature review," Journal of Engineering Education, 2024.

[8] K. Gama et al., "Combining Challenge-Based Learning and Design Thinking to teach mobile app development," 2018 IEEE Frontiers in Education Conference (FIE), San Jose, CA, USA, 2018.

[9] H. Oliveira, "A method for agile learning management based on Scrum: a case study in a CBL context," Dissertation (Master's in Computer Science) – Federal University of Pernambuco, Recife, Brazil, 2020.

[10] A. Soleymani, M. Laat, L. Itard, and M. Specht, "How networked learning can facilitate professional," Networked Learning Conference, 2022.

[11] Networked Learning Editorial Collective (NLEC), "Networked Learning: Inviting Redefinition." Postdigital Science and Education vol. 3.2, 2021, 312–325.

[12] M. De Laat and N. B. Dohn, ”Is networked learning postdigital education?” Postdigital Science and Education, 2019, pp. 17–20.

[13] E. Rusman, F. Prinsen, and M. Vermeulen. ”Unraveling networked learning initiatives: an analytic framework,” Proceedings of the 10th International Conference on Networked Learning, 2016.

[14] L. Dirckinck-Holmfeld, ”Networked learning and problem and project based learning – how they complement each other,” Proceedings of the 10th International Conference on Networked Learning, 2016.

[15] T. Ryberg, ”PBL and networked learning. In The Wiley handbook of Problem-based learning”. Eds M. Moallem, W. Hung and N. Dabbagh, 2019.

[16] S. Gallagher and T. Savage, ”Challenge-based learning in higher education: an exploratory literature review,” Teaching in Higher Education 28.6, 2023, 1135-1157.

[17] A. Hampton, A. N. Fisher, and S. Sprecher, ”You’re like me and I like you: Mediators of the similarity–liking link assessed before and after a getting-acquainted social interaction,” Journal of Social and Personal Relationships, 36(7), 2019, 2221-2244.

[18] K. Kreijns, P. Kirschner, and W. Jochems, ”Identifying the Pitfalls for Social Interaction in Computer-Supported Collaborative Learning Environments: A Review of the Research,” Computers in Human Behavior, 19, 2003.

[19] M. Charania and J. Freeland. ”The Missing Metrics: Emerging Practices for Measuring Students’ Relationships and Networks,” Clayton Christensen Institute for Disruptive Innovation, 2020.

[20] L. Carvalho and P. Goodyear, ”Analyzing the structuring of knowledge in learning networks,” 2014.