Interaction Design and Architecture(s) Journal - IxD&A, N.66, 2025, pp. 8 - 41
DOI: 10.55612/s-5002-066-001

Integrating Self-Determination Theory and Human-Centered Design to Enhance Students' Well-being in Computer Supported Collaborative Learning Environments

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Abstract. Designing for well-being in digital environments is key for fostering positive user experiences and mitigating potential harms, encompassing a broad spectrum of considerations from promoting mindful engagement and reducing addiction to ensuring fundamental accessibility. The growing recognition of technology's impact on well-being in education has led to increased emphasis on designing learning technologies with a focus on well-being. However, a gap remains in tools that support integrating well-being into the design process. This paper examines the use of an adapted evaluation based on Self-Determination Theory (SDT) within a Human-Centered Design (HCD) framework, aiming to assess its effectiveness in understanding and incorporating well-being impacts throughout the design cycle, particularly in Computer-Supported Collaborative Learning (CSCL) environments. A case study is presented, involving the redesign of a CSCL tool across three phases with students: Observation (n=6), Ideation and Prototyping (n=11), and Evaluation (n=21). The paper also discusses how integrating SDT measures into the HCD process enhances CSCL design from a well-being perspective and demonstrates its broader applicability to other learning technologies.

Keywords: student well-being, digital well-being, Self-Determination Theory, learning technologies, Computer-Supported Collaborative Learning

1 Introduction

Recent literature has given significant attention to the design of technologies with a focus on well-being, highlighting the importance of shaping technology with the goal of promoting and safeguarding well-being [1, 2, 3]. This shift reflects a growing recognition of the potential impacts that digital experiences can have on individuals.

Such impacts are ever present in education, where the widespread implementation of Technology Enhanced Learning (TEL) has brought both positive and negative effects on its users. Some of the positive impacts are enhanced learning thanks to the introduction of TEL [4, 5], technology use having positive effects on both self-directed learning and student engagement [6], and technology as a positive tool to realize effective learning [7], among others. On the other hand, reported negative effects in the use of TEL include potential issues such as "technostress" [8] as well as ongoing discussions regarding adoption barriers of technology in education (e.g. [9, 10]). Yet, despite the evidence of the recurring impact TEL has on the learning experience, we find rather few instruments designated to specifically evaluate the digital well-being experience during technology use in education, and this might be due to two main observations: 1. the concurring lack of agreement on the meaning of well-being [11, 12] and 2. the importance of including well-being in the development of new technologies, especially education, being a rather recent notion [2, 13, 14].

Regarding the first reason (1. lack of agreement on the meaning of well-being), the understanding of the term "well-being" remains somewhat elusive, with various authors reporting a lack of consensus on its precise definition [11, 12]. In some research well-being is described as a holistic, multilayered and complex concept, labeling it as a higher order construct [15] or multifaceted construct [3]. Further research takes an additional step in categorizing the term well-being by breaking it down into smaller constructs, referred to as forms of well-being [16] or well-being domains [2, 17]. Various theories and frameworks argue about the most critical or representative domains of well-being. For instance, the PERMA framework (positive emotions, engagement, positive relationships, meaning, accomplishment) [18]; the psychological well-being factors discussed by [19], such as personality, demographic factors, socioeconomic factors, genetic factors and early environment and life events; the Self-Determination theory (SDT) [20], which discusses that the threshold for well-being and flourishing stem from the fulfillment of three basic psychological needs (autonomy, competence and relatedness); or the twelve well-being domains discussed in the IEEE Recommended Practice for Assessing the Impact of Autonomous and Intelligent Systems on Human Well-Being [2]: satisfaction with life, affect, psychological well-being, community, culture, education, economy, environment, government, health and human settlement, each domain with its respective sub-domains. On the other hand, the second reason (2. including well-being in the development of new technologies) links to the necessity to consider students' well-being needs and ensure that their voices are included in the design process [21, 22], further highlighting the importance of making use of Human-Computer Interaction (HCI) techniques in the design of learning technologies [14]. This would boost the potential of TEL, since its integration, deemed necessary in today's modern education by [23], is typically favored by students during their learning experience [24, 25].

Within the specific context of technology design with a focus on well-being, [26] frame the experience a person has with technology in five spheres of impact: interface, task, behavior, life, and society. Their body of work [26] corroborates that a person's overall well-being, alongside their motivation and engagement, can be significantly improved through the fulfillment of three basic psychological needs (BPNs) across the five spheres of technology experience. Conversely, frustrating these BPNs leads to lower levels of well-being, motivation and engagement. These BPNs are identified in literature within the framework of the Self-Determination Theory (SDT), developed by psychologists Deci and Ryan [20] and initially introduced in 1985: *autonomy* (feeling self-directed and having control over one's actions), competence (feeling capable and effective), and *relatedness* (feeling connected and engaged). These BPNs are considered as crucial motivational factors in the fulfillment and achievement of well-being [27, 28, 29]. Moreover, the impact of the SDT is such that it has gained widespread acceptance in various fields, including health [30], psychology [31], business [32], and education [33, 34, 35], among others. In this work we adopt the SDT's understanding of well-being.

2 The learning experience and digital well-being in CSCL

The student learning experience in higher education has been an extensively studied theme [36, 37, 38]. Numerous reports have shown that the incorporation of technology in education has proven to be a valuable asset, significantly enhancing students' learning experiences as well as their learning outcomes [4, 5, 36, 39]. However, we find little research addressing the specific impact of learning technologies on student well-being (also referred to as student digital well-being), with current studies pointing out the importance to further contribute to the research agenda [13, 14].

In this paper we adopt the SDT's broad and foundational approach to well-being for two main reasons; Firstly, the SDT transcends individual well-being domains by emphasizing on the concept of well-being as a need satisfaction (i.e. fulfillment of basic psychological needs) [20, 26, 40], which helps understand well-being from an integrated perspective rather than a domain-specific perspective. Secondly, within the context of education, meeting these basic psychological needs inherently motivates students to learn, enhances their cognitive abilities, and prepares them for both immediate and long-term success [27, 34]. This further reinforces our rationale for employing the SDT in assessing well-being within TEL environments. Furthermore, though the SDT has an important presence in research in educational contexts (e.g. [33, 34, 35]), there is limited research in regards to applying it in the design of learning technologies (e.g. [41] discusses how the SDT aids scholars in understanding online learners' needs and teachers' challenges). In this study we explore how the SDT can be applied to proactively improve learning technology design. Our approach transitions beyond merely evaluating educational environments; instead, we use learners' BPNs satisfaction (or frustration) to directly inform and guide co-design decisions, potentially promoting learner well-being through intentional design.

For the assessment and measurement of the BPNs, there is extensive literature adapting the SDT into instruments for the various contexts it is used in (e.g. [42, 43]. While a specific instrument for the evaluation of technology use in educational contexts has not been found, in this paper we adapt and make use of the SDT-based instruments developed by [26] – i.e. the Motivation, Engagement, and Thriving in User Experience (METUX) model: a series of SDT-based questionnaires which serve as a framework for measuring and evaluating the fulfillment of a person's BPNs when interacting with technology. This model has been used in recent research (e.g. [44, 45]), with [44], in their thematic review on the ethics of digital well-being, citing it as “the most comprehensive framework for evaluating digital well-being to date”. The METUX model is meant for the assessment of the BPNs during technology use in general, but with the possibility to be adapted to the specific context of a technology, in our case learning technologies. Specifically, we make use of two of the questionnaires provided in the METUX model: the Technology Experience Need Satisfaction - Interface (TENS-Interface) questionnaire and the Technology Experience Need Satisfaction - Life (TENS-Life) questionnaire.

We apply a Human Centered Design (HCD) approach based on [58] structure, for the design of effective learning technologies built on students' learning experience. The design process is carried on through a series of HCD and HCI methods (further detailed in section 3. Methodology) to facilitate student participation in the design of the learning technology. Later on, in the evaluative phase, we make use of the selected SDT-based questionnaires, to understand whether the well-being component has been achieved or not, by observing the evolution of the BPNs fulfillment.

We carry out the HCD process on a specific learning technology of collaborative nature: a computer-supported collaborative learning (CSCL) tool, introduced in more detail in the methodology section (3.1. Context: PyramidApp in higher education). Collaboration in learning has been reported to positively contribute to well-being [46], but its effects in a digital environment come with new challenges since technology becomes an important factor. As reported by [47] and [48] the whole process of collaboration in CSCL can generate negative effects such as stress in the student, especially when there are time constraints. Furthermore, when technology takes up the lead role in learning (i.e. online learning and fully digital environments), the need to self-regulate becomes more demanding than in traditional settings [49]. [49] discuss how these aspects may end up leading to negative outcomes such as stress and negative emotions, affecting students' well-being and their learning experience.

Our main participating profiles in this study are freshmen and sophomore students (late teens) from Universitat Pompeu Fabra. The World Health Organization (WHO) [50] considers teenager years (ages 10-19) as a critical period for physical, psychological and social development. A corpus of research [51] focuses on especially the late teens – 18 to 19 years old, defining it as a transition period between early teenage years and young adulthood, coined as emerging adulthood (comprising ages from 18 to 25). During this period many changes are experienced, such as demographic changes– the transition from late teenager years to young adulthood [51], subjective changes– such as identity exploration [51], form social relationships [50], and develop a sense of responsibility and independence [50], making it a period of great sensitive change [51]. All of these changes might factor into the overall well-being of our main participating profile [52], making them key contributors to the co-design of a CSCL tool aiming to support the integration of well-being-informed features through BPN fulfillment.

Taking all these aspects into consideration, we formulate the aim of this study in one research question (RQ): *How can the Self-Determination Theory be integrated into a Human-Centered Design process to effectively identify and address factors affecting students' well-being in a Computer-Supported Collaborative Learning (CSCL) environment?* Through the formulation of a structured answer to this question, we anticipate three contributions: 1. A clearly defined methodological framework, which outlines a structured format for SDT-based co-design and provides a corresponding analysis approach for interpreting the resulting data. 2. The redesign of an existing tool to illustrate the co-design process. And 3. the formulation of a first set of well-being informed design implications based on students perceived BPN fulfillment. For easier reporting, we break down the RQ into three research objectives (ROs) following the HCD process: RO1: Set a list of design priorities - define which items affect students' digital well-being when using a CSCL tool. RO2: Ideate and prototype solutions based on the reported well-being issues. And RO3: Evaluate well-being fulfillment (through BPN fulfilment) of current vs new designs proposed by students. These ROs, as well as the methodology are further discussed in section 3. This is followed by the results and evaluation sections. We then discuss the design implications, limitations, and conclude with future directions for work.

3 Methodology

3.1 Context: PyramidApp in higher education

This paper investigates the RQ through a case study of an existing tool: PyramidApp. PyramidApp is used as a non-trivial computer-supported active learning environment. It is a CSCL tool that implements the pyramid collaborative learning flow pattern, also referred to as the "snowball" method [53]. The collaborative and scripting aspect of the tool helps enhance the social interactions between students, leading to fruitful learning [53, 54]. PyramidApp is regarded as the tool of research since it provides two elements needed to carry out this specific study: being an active learning technology and the involvement (familiarity) of students with the tool. As students are familiar with the tool it minimizes novelty effects and enables students to engage in design processes. The features of the tool include, among others (see Table 1), a group awareness feature [55] to show students their level of contribution in the discussion and an orchestration dashboard for teachers to monitor students' progress and modify the activity on the fly. These features are common in learning technology tools, especially in CSCL.

Table 1. PyramidApp functionalities.

Functionality	Level	Type of functionality
Timer	Individual, Collaborative	A timer to inform the participants how much time is left in the current level.
Individual answer	Individual	In the first level of the pyramid, students are to come up with an answer on their own to the presented question.
Skip task	Individual	In the first (individual) level, students are given the option to skip if they don't wish to answer. (after a period of inactivity).
Collaborative editor	Collaborative	Students get to use the collaborative editor once they reach the collaborative level.
Task rating	Individual, Collaborative	Each time a level is completed, students can individually rate (1st part of collaboration) the individual and collaborative answers. All the answers advance to the next collaborative level for improvement (2nd part of collaboration), ordered from most to least rated, showing the rating mean as well.
Chat	Collaborative	A space where students get to interact and share their ideas as well as collaborate in real-time.
Social awareness bar	Collaborative	A function that increases based on the number of messages sent through the chat. Each student is assigned their own social awareness bar, which is also visible in public.

The type of activities that can be carried out in PyramidApp require students to debate a specific question within a limited timeframe. Students have to collaborate in groups and decide on a final answer that is discussed in a minimum of two levels (the first level being individual, and the rest collaborative). The number of levels and timeframe is determined by the professor. The whole process is carried out in real-time, and students have to come up with a final, collaborative answer. Each collaborative level has a rating phase and a collaborative improvement phase. Both the individual and collaborative phases have time limits – the teacher can modify the times through the orchestration dashboard. The formation of groups is random. PyramidApp is usually introduced to undergraduate engineering students during their first-year introductory course Introduction to Information and Communication Technologies (ITIC), carried out at Universitat Pompeu Fabra– though we must clarify that the tool itself is not limited to this target. During this course, students are introduced to the concepts of stress and performance through the Yerkes and Dodson law [56], which are two key components of both education and well-being [2, 55, 57]. Therefore, we take PyramidApp as the tool to help us understand how we can support these student stress-performance situations, which affect their learning experience and well-being.

3.2 Co-design process: participants, instruments, and methods

Our co-design process is framed in the HCD structure of [58]: 1. Observation, 2. Ideation, 3. Prototyping and 4. Testing. An overview of the co-design process, research methods, research objectives (ROs) and participants' profile can be seen in Table 2, and a visual representation of the process in Figure 1. In the following subsections (3.3, 3.4 and 3.5) we will be providing further details (goals, methods and participants) of each one of the HCD phases, before addressing the respective results of each phase in section 4. Results.

Table 2. HCD process overview

HCD phase	Research method	Research objectives (ROs)	Participants
Observation	Focus group: - Lotus method - Stress-performance matrix	RO1: Set a list of design priorities - define which items affect students' digital well-being when using the tool.	**n=6**: 2 Ph.D. students, 2 graduate and 2 undergraduate students
Ideation and Prototyping	DAKI method: - Low-fidelity prototypes - High-fidelity prototypes	RO2: Ideate and prototype solutions based on the reported well-being issues.	**n=11** ITIC – undergraduates (1st and 2nd year students)

Testing/ Evaluation	METUX measures: - Interface (TENS-Interface) and Life (TENS-Life) questionnaires Evaluation of results: - Qualitative (thematic analysis) - Quantitative (Cronbach's alpha, and Wilcoxon signed-rank)	RO3: Evaluate well-being scores of current and new designs proposed by the students, to compare BPN fulfillment and significance.	**n=21** ITIC – undergraduates (1st and 2nd year students)

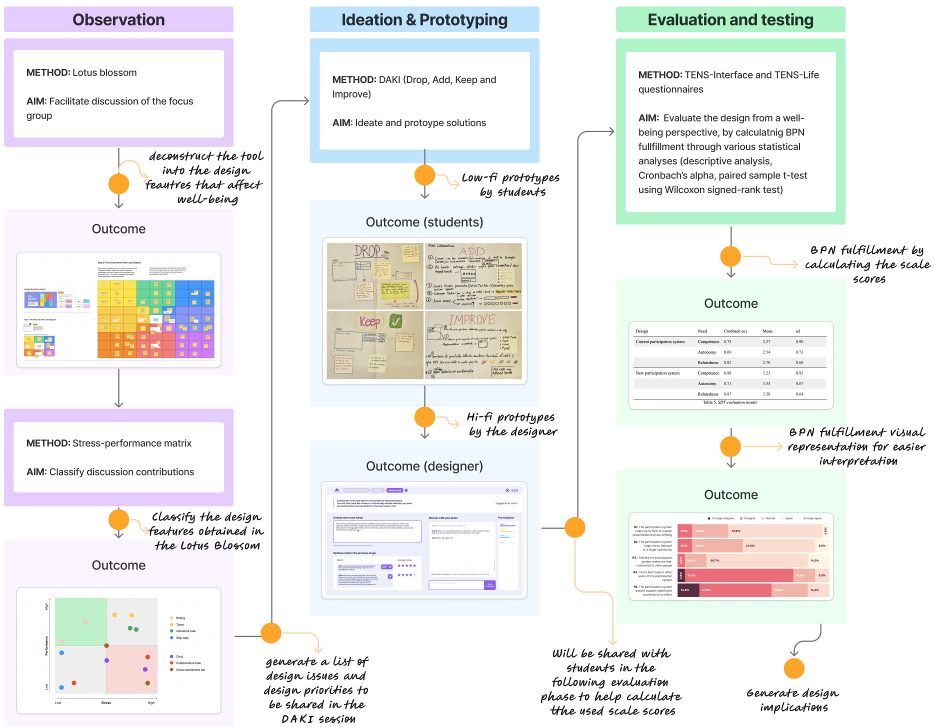

Fig. 1. HCD process visual overview.

3.3 Observation phase: Focus group

The first phase consists of a focus group, a research technique proven to be effective in gathering in-depth information about people's thoughts, experiences, and attitudes [59]. [60] highlight the unique richness of collected insights when focus groups are used in mixed methods studies. The participants of this phase are students that have used PyramidAPP in real learning situations within the classroom. The

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workshop had two editions of 90 minutes each (one online and one f2f) and a total of 6 participants working in teams of 3, their profiles ranging from undergraduate students to graduate and Ph.D. students. The hosting space for discussion and ideas was the online collaborative board FigJam. This first session's goal is to break down PyramidApp into its essential features and detect where the issues that affect the learning experience of the students emerge from (first segment). Once the issues are identified, these are to be classified into a list of priorities (RO1), depending on the grade they affect the students' learning experience (second segment).

First segment – Lotus blossom method: The lotus blossom method [61, 62] is a structured brainstorming technique that begins with an initial idea and expands into related concepts, breaking down complex topics into simpler ideas. [62] describe it as a tool that fosters creative thinking and stimulates students' conceptual development.

For this specific workshop, we part from the main topic, which is "PyramidAPp, stress and performance", the first level within the lotus. The second level begins with the workshop facilitator providing a list of PyramidApp's main functionalities as a starting point. Students then evaluate these functionalities, considering their potential impact on students' stress levels, given their familiarity with the tool. They also have the opportunity to propose additional secondary functionalities they deem relevant or remove ones from the first list (see Table 1), with the workshop facilitator's role being managing the time, explaining instructions clearly, leading participants through each activity, and encouraging participation from all students during the discussions. In the third level students further break down the functionalities of the second level and give their feedback based on their perception of each functionality and how it affects their learning experience and well-being (based on stress and performance) with PyramidApp. In the context of this paper, we apply the lotus blossom with the aim to facilitate the discussion between participants in the focus groups, which will later on aid them in classifying their contributions in the second segment – stress and performance matrix.

Second segment – Stress and performance matrix: To classify the participants' answers given during the lotus activity segment, they are asked in turn to place each one of the functionalities of the first level of the lotus activity in a matrix of value (representing the levels of stress and performance, based on the Yerkes & Dodson law representation – [56]) plus a brief reasoning behind the placement they choose. The objective is to detect which functionalities are placed more frequently (by participants) in the matrix area with more risk (i.e., low performance / high stress). This also helps generate a list of design priorities (RO1).

3.4 Ideation and prototyping phase: Drop, Add, Keep, Improve (DAKI) method

The high priority functionalities of the previous phase are to undergo a four-part process called DAKI [63, 64]. The DAKI method is a retrospective tool that helps reflect on a design process by evaluating what should be discontinued (drop), what could be added from scratch (add), what works adequately and requires no improvements or removal (keep) and what is existing but needs improvement (improve). Its flexibility is such that it can be used in either phase of the design process [63]. Students are given a list of issues and observations from the previous Observation phase. We part from the following prompt: Redesign the functionalities with what you consider important to you during your learning experience in PyramidApp. The total number of participants in this activity is 11 (1st and 2nd year students, distributed in 3 groups of 4, 4, and 3), all students from the PyramidApp. The duration of the activity is 120 minutes. The students distribute this time and allocate what they deem necessary to each part of the DAKI. The results we expect from the DAKI method is that being a retrospective tool, students can reflect on the data that has been collected until this point, and they get to decide and tailor (through the design of low fidelity prototypes) what is truly important to them in terms of tool functionalities' redesign (RO2). Once the low-fidelity prototypes are finished, the main author will generate high fidelity prototypes to be used in the evaluation phase.

3.5 Evaluation phase

We apply a mixed method approach: a quantitative and qualitative analysis.

Quantitative analysis. The goal of this analysis is to evaluate the new designs by whether they fulfill or frustrate the BPNs in comparison to the current designs (RO3). To achieve this, the SDT-based instruments of TENS-Interface and TENS-Life [26] are used. The METUX model [26] presents a variety of SDT-based questionnaires, to be used depending on the spheres of experience to be evaluated. We chose the Technology-based Experience of Need Satisfaction-Interface (TENS-Interface) questionnaire since the resulting designs are from the improvement of elements of the interface of PyramidApp. Though for one of the BPNs (competence), we make use of the Technology-based Experience of Need Satisfaction - Life (TENS-Life) to evaluate some aspects that escape the interface sphere and fall into the life sphere, mainly due to the tool's participation system component; functionalities that involve analytics (e.g. visual analytics) are not usually interactive components of the interface, but rather informative components, therefore their “interactiveness” cannot be truly measured or evaluated. As a consequence, we had to take a broader set of questions that TENS-Life provided.

Table 3. Used set of adapted questions.

Need and questionnaire	Scale	Adapted questions
Competence	TENS-Life	(C1) The (current/new) participation system has made me feel insecure about my abilities. (-) (C2) The (current/new) participation system has affected me negatively in my life. (-) (C3) The (current/new) participation system has lowered my confidence. (-)
Autonomy	TENS-Interface	(A1) The (current/new) participation system provides me with useful options and choices. (A2) I feel pressured by the (current/new) participation system. (-) (A3) The (current/new) participation system feels intrusive. (-) (A4) The (current/new) participation system feels controlling. (-)
Relatedness	TENS-interface	(R1) The (current/new) participation system helps me to form or sustain relationships that are fulfilling. (R2) The (current/new) participation system helps me to feel part of a larger community. (R3) The (current/new) participation system makes me feel connected to other people. (R4) I don't feel close to other users of the (current/new) participation system. (-) (R5) The (current/new) participation system doesn't support meaningful connections to others. (-)

The participating students in the evaluation are a total of n=21 (1st and 2nd year students), 20 of which are students that did not participate in the previous phases of the co-design process, but are still highly familiarized with PyramidApp as they have experienced its use in their courses, i.e., through real learning situations in the classroom. The questions focus on both current and redesigned PyramidApp features– the latter evaluated through a high-fidelity prototype. Both current and new features are to be compared in terms of BPNs fulfillment – i.e., the effectiveness of the new features will be achieved if the BPNs are fulfilled in higher numbers than the current features. We calculate the internal consistency of the results with Cronbach's alpha (α) and the resulting mean of each need. The questions are presented on a Likert scale ranging from 1 to 5 (1 being completely disagree, 5 being strongly agree), with reversed items marked with a "(-)" (Table 3).

For the sake of clarity, the current and redesigned features heavily focus on the participation system of PyramidApp, therefore the questions are highly based on said participation system and how it fulfills the students' needs in both current and new designs. For more insight, students are also asked to justify their questionnaire scoring through a brief reasoning. Afterwards, we carry out a paired sample t-test using Wilcoxon signed-rank in order to assess whether the design changes have significantly impacted the BPNs fulfillment of students. The significant results derived from the quantitative analysis will be highlighted and discussed in section 4. Results.

Qualitative analysis. When evaluating the participation system's new features, students are encouraged to provide feedback on each feature. The first author conducts a thematic analysis of the collected data, initially coding the feedback based on each feature (pros and cons): students are asked to share their thoughts on each feature and to identify both the positives and negatives. Once this step is completed, the pros and cons are further coded according to the BPN they affect, basing the coding criteria on the characteristics of each of the three needs (autonomy, competence and relatedness). The data collection was carried out on an individual basis (i.e. individual responses) through a form with the following questions:

- Please state your opinion on the new chat and outline the positive aspects of its implementation, in comparison to the current version.
    - And what are the negative aspects of implementing the new chat, compared to the current version?
- Please share your opinion on the new collaborative editor and what the positive aspects of implementing it are, compared to the current version.
    - And what are the negative aspects of implementing the new collaborative editor, compared to the current version?
- Please share your opinion on this new participation bar and what the positive aspects of implementing it are, compared to the current version.
    - And what are the negative aspects of implementing the new participation bar, compared to the current version?

As the questions partially categorize feedback into positive and negative, the thematic analysis follows a similar scheme.

4 Results

4.1 Observation phase results

The interventions of both editions of the focus groups (n=6: g1=3; g2=3) revolved around the discussion of the seven introduced functionalities (see Table 1), which later on got individually broken down through the lotus method. Students identified the stress and performance components of each functionality, and how these affect their learning experience with the PyramidApp. We can see a visual representation of the results in Figure 2: high priority items are placed in the red quadrant, whereas the lower priority ones are placed in the green quadrant. The gray quadrants represent mid-priority items. Students identified the social awareness bar, chat, and collaborative task (highlighted in their corresponding colors from Figure 2 in Figure 3) as the most problematic features in terms of stress and performance during their experience with the PyramidApp (in the red quadrant). Students report that these features share interconnected issues, resulting in the following list of concerns for the upcoming Ideation phase.

(1) Social awareness bar: Students from both focus groups consider that the social awareness tool, one of the functionalities involving visual analytics, does not provide valuable information for their learning experience. What they consider of value is the representation of their participation, performance, and collaboration (participation acknowledgement). They want a tool to represent more nuanced information regarding their participation (they define it as a "participation bar"– though it is more centered around contribution rather than only participation) instead of a social awareness bar.

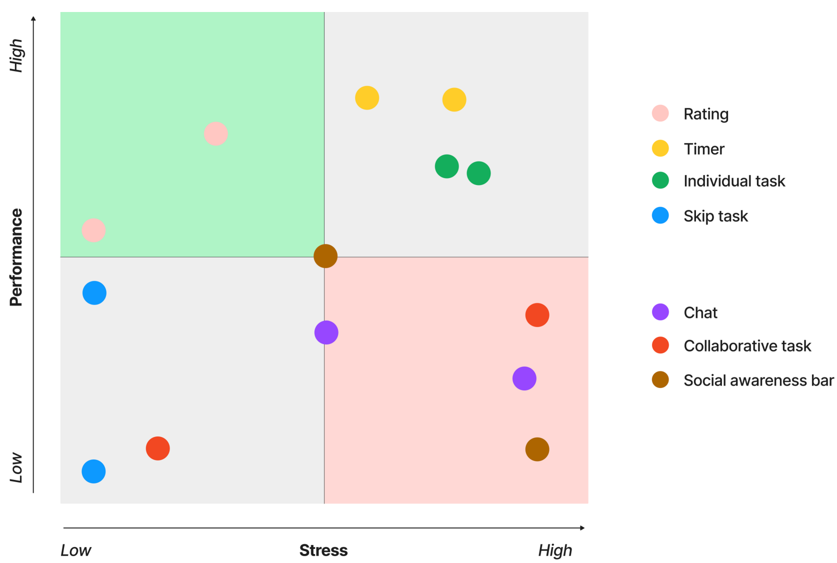

Fig. 2. Matrix of stress-performance representation (placement of both participating groups).

(2) Chat: Banning the possibility of spam could lead to students using the chat more seriously. Therefore, participation could also be impacted, since spam would no longer be rewarded (through the social awareness bar), but rather using the opportunity to message as an important asset to truly collaborate with their peers.

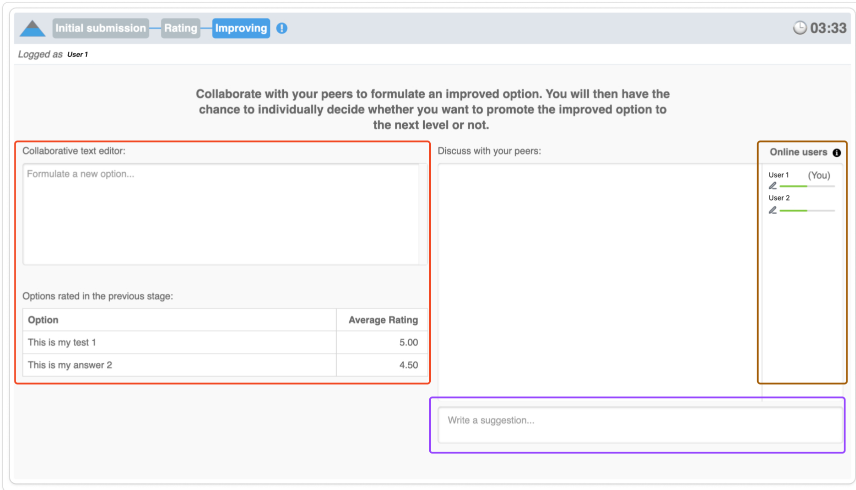

Fig. 3. Current design of PyramidApp. Chat, collaborative task and social awareness bar are highlighted.

(3) *Collaborative task*: The current collaborative editor does not support the collaboration in real-time by multiple members, which proves to be a deal breaker of student collaboration. Furthermore, and connected with the social awareness tool (only using data from the chat), students do not see their collaboration reflected through participation, which they consider to be something of value. They want their collaboration to be acknowledged in a fair way through a new participation system (i.e. "participation bar").

4.2 Ideation and prototyping phase results

All three groups (n=11: g1=4; g2=4; g3=3) worked closely together since the issues and ideas they generated were involving the three functionalities most of the time. After discussing the provided issues of the Observation phase, each group carried out a DAKI session with their assigned functionality (either chat, social awareness bar or collaborative editor) following the given prompt (Redesign the functionalities with what you consider important to you during your learning experience in PyramidApp). Once all groups finished, they discussed and merged their ideas to prototype a common solution. Their solution mainly focuses on what they consider "a fair participation system" within PyramidApp. Fairness is an ongoing theme in CSCL (e.g., "fairness of work distribution is positively related to active participation" – [65]). Students consider the actual (un)fairness (in the representation of their participation) to be the root cause of most issues presented by their peers in the previous HCD phase (Observation).

(1) A participation system that recognizes previous authorship: in PyramidApp, the most-rated options of each level are brought forth in the next level for their further improvement. Until now, students directly copied and pasted the most-rated option into the collaborative editor, giving no recognition to the original author(s) of the option. To creatively counter that, if a group of students decides to reuse one of the options, they propose the use of a new “edit this option” button (instead of copying and pasting). This button may do two things: (I) Directly copies the text within the collaborative editor. (II) Most importantly: Acknowledges the contribution of the original author as well as the editing author (in the form of participation points through a participation bar), making the concept of “participation” more fair and collaborative for students.

(2) A participation less centered in chat messaging (social awareness) and more focused on collaboration and participation (participation acknowledgement): Using the chat is still an essential tool for students to collaborate and communicate, but sometimes it is not used properly (e.g., spamming, talking about topics outside the scope of the activity). To counter that, students ideated the following: (I) Now spam is countered by a “slow-mode” system (only 1 message is allowed every 10 seconds) that activates once it detects spam. This function intervenes to help students regulate their actions when spam is detected. (II) Messages are still counted as participation, but students cannot exploit it (to “cheat” the participation points). (III) Students are to use the opportunity to message more seriously, rather than send random messages.

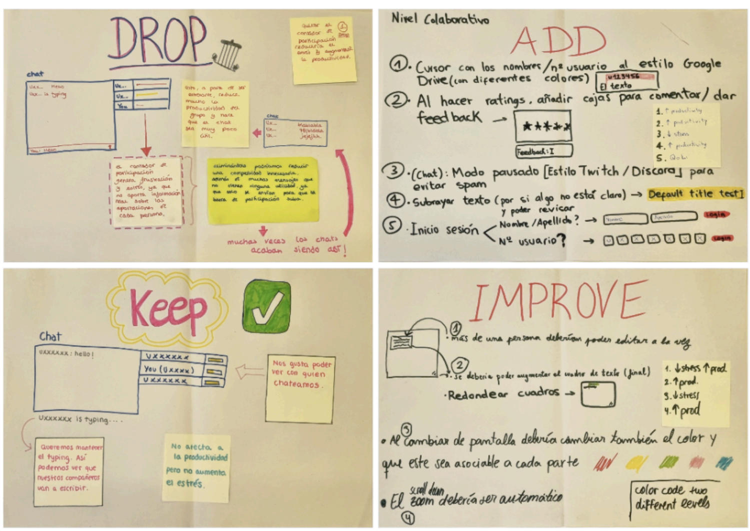

Fig. 4. Some of the low-fidelity prototypes.

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DOI: 10.55612/s-5002-066-001

All these improvements and ideas are reflected through sketches and prototypes presented by the students (Figure 4). Later on, these sketches and prototypes are used to design a high-fidelity prototype (Figure 5) – designed by the first author, which is going to be used for the final evaluation phase. Last but not least, we have observed that students seem to value visual representation of their progress in the interface (i.e., something they can keep track of in real-time), leading them to represent their improvements mainly through interface visual analytics.

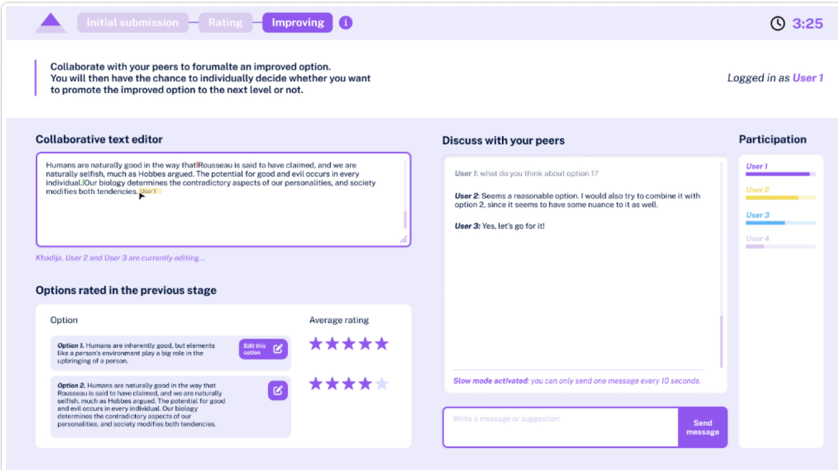

Fig. 5. High-fidelity prtotype.

4.3 Evaluation phase results

Quantitative data analysis. Table 4 presents the comparative results between the evaluation of the current features of PyramidApp and the evaluation of the new features based on students' proposals as co-designers. This Evaluation phase was carried out using the SDT instruments (introduced in section 3.5) with n=21 undergrad students, also highly familiarized with PyramidApp from which 20 did not participate in any of the previous phases of co-design in an effort to reduce bias. We assess the reliability using Cronbach's α to support the use of SDT instruments in measuring the three BPNs, and we examine the evolution of results by comparing mean scores between the current and new participation systems.

Table 4. SDT evaluation results.

Design	**Need**	**Cronbach (α)**	**Mean**	**sd**
Current participation system	Competence	0.75	2.94	0.90
	Autonomy	0.69	2.80	0.73
	Relatedness	0.82	2.30	0.68
New participation system	Competence	0.88	3.57	0.92
	Autonomy	0.71	3.55	0.67
	Relatedness	0.87	3.69	0.64

The results show that the newly designed features fulfill the students' BPNs more than the current ones, both through consistency of results and the general mean. Competence and autonomy have a considerable improvement within the newly designed features: competence (mean=2.94 vs mean=3.57)– Figure 6.1 and Figure 6.2, and autonomy (mean=2.80 vs mean=3.55)– Figure 7.1 and Figure 7.2. The biggest jump is seen across relatedness (mean=2.30 vs mean=3.69)– Figure 8.1 and Figure 8.2. Students justify this with an improved sense of belonging and community appreciation (since their work and participation are being acknowledged by said community). In order to test if the results are significant, we apply a paired sample t-test using Wilcoxon signed-rank test (since our data is not normally distributed). The results are in table 5, with significant results flagged in bold.

Table 5. Paired samples t-test results – Wilcoxon signed-rank test

Measure 1 (pre)	Measure 2 (post)	Z	p-value
PRE-Competence	POST-Competence	-2.657	**0.008**
PRE-Autonomy	POST-Autonomy	-3.024	**0.003**
PRE-Relatednes	POST-Relatedness	-3.920	**<.001**

All constructs display a significant jump from pre to post, representing values below 0.01, and demonstrating the impact of the design changes on the fulfilment of the BPNs.

We further analyze the changes on each item. For competence need (Figure 6.1 and figure 6.2), even though all three items scored higher in terms of BPN fulfillment in the new design, the only significant change is that of item C2, with the feelings of negative affect being reduced greatly.

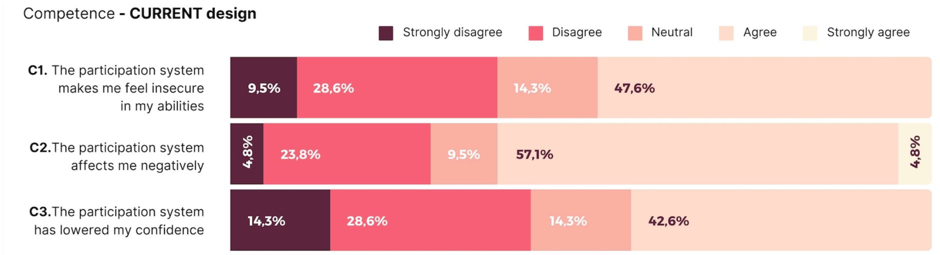

Fig. 6.1. Current design – competence need.

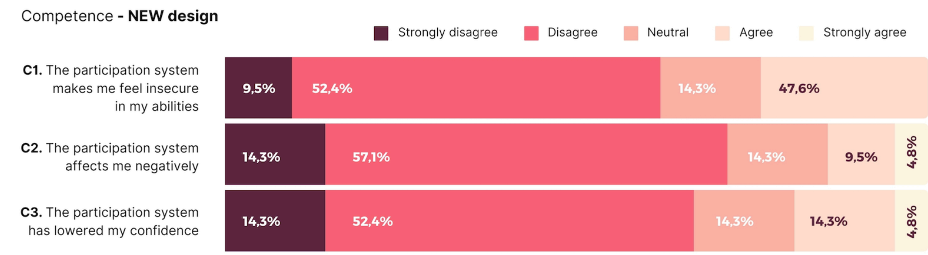

Fig. 6.2. New design – competence need.

As for autonomy need (Figure 7.1 and Figure 7.2), all four items also scored higher in terms of BPN fulfillment in the new design, with the only statistically significant change being A1. “The participation system provides me with useful options and choices”.

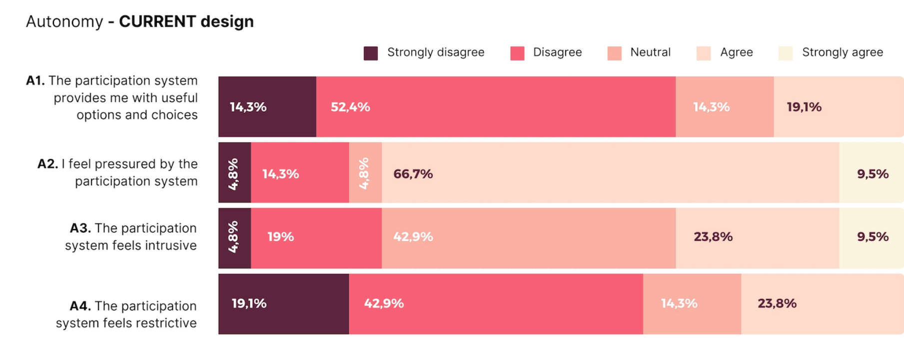

Fig. 7.1. Current design – autonomy need.

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DOI: 10.55612/s-5002-066-001

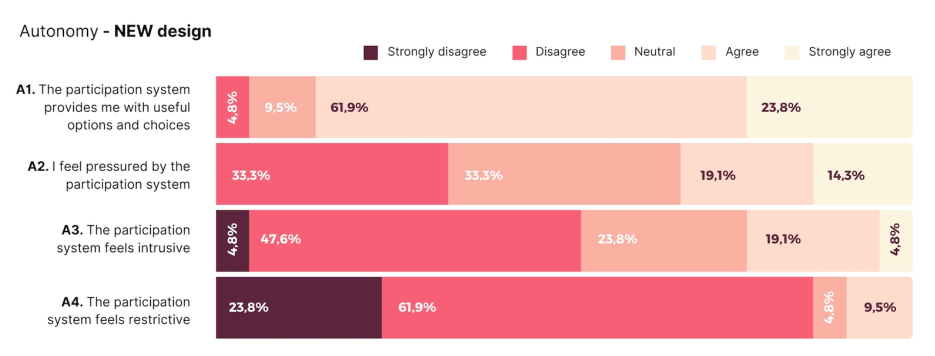

Fig. 7.2. New design – autonomy need.

Finally, for relatedness need (Figure 8.1 and Figure 8.2), we can see a higher BPN fulfillment rate in items R1, R2 and R3 as well as a lower BPN frustration rate in items R4 and R5. Unlike the other two needs, relatedness need is the only one where all items have had a statistically significant change. This could imply that the relatedness need has been the most affected (positively) by the changes made in the participation system.

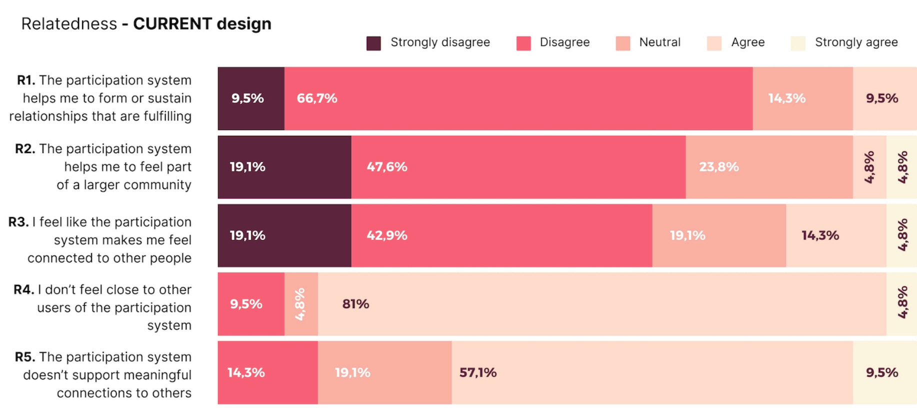

Fig. 8.1. Current design – relatedness need.

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DOI: 10.55612/s-5002-066-001

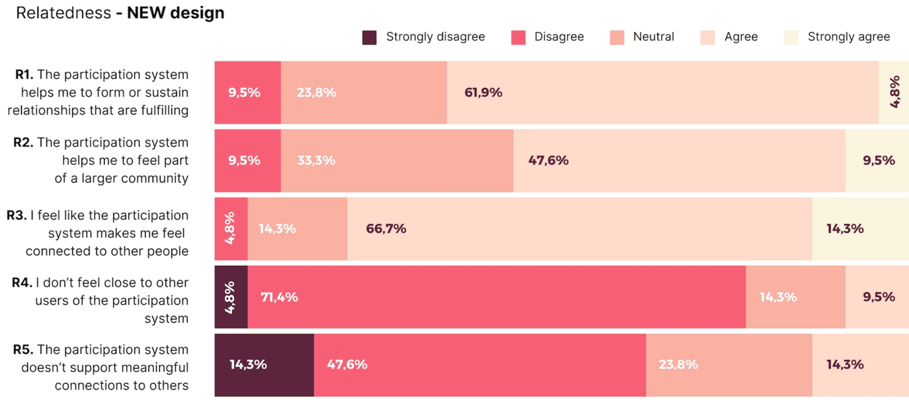

Fig. 8.2. New design – relatedness need.

Qualitative data analysis. As introduced in section 3.2.3, the first author analyzes the qualitative data collected from the resulting evaluation of the new participation system through a thematic analysis, examining each redesigned feature it incorporates (Table 6). The analysis highlighted potential benefits and drawbacks based on qualitative insights from students and the main affected BPN. Sentences in italic are students' comments, and similar interventions by other students are indicated with the letter S plus a unique assigned number to each student (e.g. S12). The table below summarizes the observed shifts provided by the students. It is important to keep in mind that all observations are students' perceptions on how such changes can impact a real-world setting, if the improvements were to be implemented in the PyramidApp.

Table 6. Summary of student feedback. *Coding proposed by the main author.

Redesigned feature	**Observed shift (theme)**	**Observations with students' comments**	**Main affected BPN***
Chat in slow mode (pros)	1. Improved workflow by reducing the cognitive load	*"It significantly improves the workflow since it restricts the type of message sent, making the user pay more attention."* (S3, S4, S5, S7, S9, S10, S11, S12, S13, S16, S18).	Autonomy
	2. Avoids spam	*"It* (new chat) *avoids the spam that its sole purpose is increasing the*	Autonomy

		participation bar". (S1, S6, S7, S9, S10, S11, S13, S17, S18).	
	3. Focused engagement	*"People send more serious messages".* (S4, S7, S8, S9, S10, S11, S15, S16, S17, S19, S20, S21).	Competence
	4. Balanced communication	*The communication between the members of the group gets balanced".* (S11, S14, S16).	Relatedness
Chat in slow mode (cons)	5. Time and productivity management	*"For a person that usually takes the lead in these activities, the slow-mode can be a blunder". Thus, they propose "only students that generate spam to be imposed with the slow-mode".* (S1, S2, S4, S7, S8, S10, S11, S15, S19, S20, S21).	Autonomy
Participation bar (pros)	6. Fairness	The new participation bar is defined as "*fair*", "*just*" and "*empathetic*" in the acknowledgment of students' work. (S2, S4, S5, S7, S9, S10, S11, S12, S13, S14, S15, S16, S18, S19, S20).	Competence
	7. Balanced participation bar	*"Spam is no longer rewarded as participation points thanks to the slow-mode".* (S13, S15, S18).	Competence
	8. Enhanced collaboration	Since acknowledgment of contribution (through participation points) goes both ways (original author of an answer and the editing author), it gives a sense of *"greater collaboration".* (S2, S5, S6, S7, S13, S18, S19).	Relatedness
	9. Nuanced participation	Interacting in the various tool spaces boosts participation, rewarding the collaborative actions. Students emphasize this for building participation, fostering "*healthy competitiveness"* and individual accountability [74]. (S1, S3, S7, S14, S21).	Relatedness
Participation bar (cons)	10. Cheating the participation points	Students might still find creative ways to increase their participation just by interacting without the purpose of collaboration. One of the suggestions (by S10) to avoid these cases was: *"Perhaps the participation bar could keep track of other factors like the length of the answer, the time it takes one to edit an answer and the coherence of the produced answer, which could*	Competence

		bring more insight on the students' performance through the participation bar". (S1, S3, S6, S9, S11).	
	11. Environmental effects	Another tension is that the actions that may happen outside the tool, depending on the scenario, may not have a reflection in the tool. Or that in the social regulation of the activities the students nominate a role to write the final answer based on the agreements in the chat. The nominated student represents the group, not an individual contribution. (S20).	Relatedness
	12. Awareness effects	One more element of concern is the effect of how awareness or "*being watched"* can have a negative and pressuring effect on learning [75]. (S4)	Autonomy
Collaborative editor (pros)	13. True collaboration	The new editor supports collaboration by multiple students. Now, *"writing does not befall on just one student".* (S1, S2, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S18). Showing who is currently editing also counts as a *"plus".* (S2, S3, S4, S5, S8, S10, S11, S14, S15, S17, S21).	Relatedness
Collaborative editor (cons)	14. Disorganized editing	One of the negatives is related to having *"way too many people edit at the same time",* if the groups are big. (S6, S9, S18, S20, S21).	Autonomy

5 Discussion

This section discusses the study's findings, emphasizing their implications for student well-being and the design of effective CSCL tools. Our paper contributes with an answer to the RQ of "How can the Self-Determination Theory be integrated into a Human-Centered Design process to effectively identify and address factors affecting students' well-being in a Computer-Supported Collaborative Learning (CSCL) environment?". The answer is provided in the previous sections as an articulation of a structured design process focused on the student perspective: we make use of an adapted evaluation based on the Self-Determination Theory (SDT) and integrate it into the latter stages of the HCD process as an effective testing method. Fulfilling (or frustrating) the BPNs of the SDT gives us insight on student well-being improvement (or frustration). A case of a CSCL tool is used to illustrate the approach and to derive design implications that show how the integration of students' voices and the leveraging of SDT instruments in the HCD process open new avenues in the research around how to design effective learning technologies. Through directly addressing what frustrates students in PyramidApp (RO1) and later on proposing tailored solutions (RO2), students showed the ability to reflect about how to positively influence their basic psychological needs through design decisions (RO3), at least when using high-fidelity prototypes. This positive result indicates potential and encourages applying such design processes in real-world contexts, leading to opportunities for future research that evaluates their real-world impact.

As we dive into the discussion, we cross-check the results by encompassing the obtained quantitative and qualitative data, discuss their impact on the RQ achievement and later on generate the relevant design implications. We start with the main takeaways of this paper, categorized by BPN for easier reporting, and always keeping in mind that all reported changes (positive and negative) are students' perceptions based on the high fidelity prototype versus the current state of the PyramidApp, and they rest to be tested in a real world setting (i.e. properly developed into the PyramidApp):

Competence: The most significantly impacted item when analyzing the SDT data is item C2 - "The (current/new) participation system has affected me negatively in my life (-)". The perceived change was positive, which is further observed in the mean increase of the scale when analyzing the overall competence of the current vs newly proposed participation system (mean=2.94 vs mean=3.57). The specific features contributing to this significantly positive change are the following (refer to table 6): 1. The focused engagement (Chat in slow mode), 2. Fairness (Participation bar) and 3. Balanced participation bar (Participation bar). As for the element negatively impacting competence is 1. Cheating the participation points (Participation bar), which is still a students' concern.

Autonomy: The most significantly impacted item in autonomy when analyzing the SDT data is item A1 - "The (current/new) participation system provides me with useful options and choices". The perceived change was positive, which is also observed in the mean increase of the holistic evaluation of autonomy in the current vs new participation system (mean=2.80 vs mean=3.55). As for the specific features positively contributing to the autonomy, these are (refer to table 6): 1. Improved workflow by reducing the cognitive load (Chat in slow mode) and 2. Avoid spam (Chat in slow mode). As for the items negatively impacting autonomy, these are: 1. Time and productivity management (Chat in slow mode), 2. Awareness effects (Participation bar) and 3. Disorganized editing (Collaborative editor).

Relatedness: As for relatedness, it is the need that has seen the most significant improvement, also observed in all of its items: R1 - "The (current/new) participation system helps me to form or sustain relationships that are fulfilling", R2 - "The (current/new) participation system helps me to feel part of a larger community", R3 - "The (current/new) participation system makes me feel connected to other people", R4 - "I don't feel close to other users of the (current/new) participation system (-)", R5 - "The (current/new) participation system doesn't support meaningful connections to others. (-)". (mean=2.30 vs mean=3.69). The features impacting this positive change are: 1. Balanced communication (Chat in slow mode), 2. Enhanced collaboration (Participation bar), 3. Nuanced participation (Participation bar), True collaboration (Collaborative editor). As for the item still negatively impacting relatedness is: 1. Environmental effects (Participation bar).

The formulation of these results was facilitated thanks to the structure provided by the HCD process paired with the SDT approach. Combined in a co-design approach, students were capable to reflect on and report which features of the CSCL tool affected their well-being (RQ), as well as reflect on the perceived impact the newly designed high-fidelity features might have if implemented in a real-world setting. The present work serves as an example which can facilitate its replication in similar cases, as well as help identify and generate a first set of relevant BPN-informed design implications, which are listed in the following subsection.

5.1 Identification of relevant well-being factors in CSCL and design implications

In this section, we delve into the design implications which derive from the cross-checked qualitative and quantitative results around the optimization of the participation system of PyramidApp. These implications shed light on how designers should prioritize competence, autonomy and relatedness needs, as well as embracing enhanced fairness and fostering collaborative learning dynamics while addressing potential drawbacks in similar CSCL tools, for an improved learning environment that promotes both student well-being (through BPN satisfaction) and enhanced learning experience. The implications are summarized in the following points, each related to the mainly affected BPN (keeping in mind that, ultimately, BPNs are interrelated to a degree, therefore some implications might represent other BPNs but to a lesser degree than the main one).

Relatedness: 1. A fair, empathetic and collaborative participation system: Students' perception of the new participation system is that it encourages fruitful interaction, collaboration, and a sense of community among students. As well as rewarding individual contributions, discouraging spam-like activities and acknowledging collaborative efforts which help foster a positive social environment. *2. Collaborative editing support*: Students' perception of the new collaborative editor is that it positively contributes to relatedness and encourages true collaboration in real time (e.g. Google suite), unlike the previous editor that could only allow one person at a time. However, designers should address issues like disorganized editing when many students edit simultaneously in larger groups.

Competence: 1. Maintain a balance between rewarding participation and avoiding cheating: Students perceive the new participation bar as fair and empathetic, and it discourages spam. Designers should balance fairness and accountability, and consider additional factors beyond quantity, like the quality and coherence of contributions. *2. Minimize distractions and information overload*: Students' perception of features that can potentially reduce cognitive load, like the slow-mode chat, can be beneficial. Designers should continue exploring ways to minimize distractions and information overload for students, leading to a more focused and productive engagement. *3. Address chat potential drawbacks*: While the slow-mode chat has advantages, its potential perceived drawbacks (e.g., time management issues for "leader" students) need to be considered. Designers should find ways to customize features or incorporate student feedback to mitigate these challenges.

Autonomy: 1. Consider the impact of students' awareness of being monitored: Designers should consider the impact of perceived social awareness (through the participation bar) on students' autonomy and learning. *2. Impact of external environmental factors on tool interaction*: Designers should also be mindful of perceived external environmental factors happening outside the tool's digital environment, such as the physical learning environment, which may affect the experience within the tool.

One of the main aspects contributing to students' perceived BPN fulfillment is the role of the participation bar in the learning experience: we observed that students perceived a certain value in following part of their learning flow through a fair visible metric (participation bar), making awareness of the learning experience more present as well as acknowledging their contributions in the process. This finding is connected to recent research on how visual-narrative interfaces are favored – at least by teachers [66]. Students also seem to perceive value in being able to see how their learning process advances, which seems to generate a "sense of initiative" compelling them to improve both their individual performance and group performance through collaboration. Furthermore, [3] in recently reported guidelines for well-being supportive design, discusses that for this kind of informational feedback (i.e. participation bar) to be fully autonomy supportive it must not come with an element of pressure [67]– as reported by some students it can be seen as pressuring if the information is visible to the public (awareness). Otherwise, the feeling of "being evaluated, judged or surveilled" might prove counterproductive [20].

Another key aspect is the perceived use of the slow-mode chat to support co-regulation by minimizing distractions and information overload: the ability to stop spam when detected, can potentially lead and contribute to co-regulation [68, 69] as well as taking the opportunity to communicate more serious messages and avoid "off task" messaging [70]. This functionality (slow mode) exists in streaming platforms like Twitch and Discord. Though we have not found, to the best of our ability, any relevant literature applying it to learning situations involving CSCL. In regard to design, it can be autonomy-frustrating if it feels controlling (according to the well-being design guidelines – [3]). However, if the slow mode feature supports reflection using supportive communication [71] (e.g. a message indicating that "chat is a space to foster collaboration with your peers, therefore taking your time to message might be good to help you reflect on what you want to communicate to your peers" once spam is detected), it can foster autonomy and competence according to the same set of guidelines [3]. Partially connected to this last point, the perceived blunders of time (another element of pressure, especially for "lead" students) when chat is in slow mode can be easily countered, since the teacher can control the timer if students need more time to complete the activity. This is one way in which PyramidApp currently addresses the negative effects of time limits – also pointed out by students during the design process, and the reason why the time was not considered as a high stress element as it would be normally expected. Therefore, addressing time-related pressures by allowing teachers to control the timer has the potential to enhance students' learning experience.

All these previous findings are quite in line with what is expected from the fulfillment (or frustration) of the BPNs: SDT defines "basic psychological needs" as those satisfactions that [26]: a) are inherently rewarding/motivational (e.g. acknowledgement of the student's work), b) when satisfied lead to flourishing – i.e. well-being (e.g. fairness in the acknowledgement of the student's work) c) when frustrated lead to negative experience (e.g. spam). Furthermore, we observe that by connecting the design process to the SDT can prove effective in highlighting possible areas of the design of learning technologies that affect the students' perceived learning experience and well-being. The design of some components (i.e. slow mode chat) can have well-being impacts if not designed accordingly, frustrating the BPNs. We find that it can also become relevant from an ethical point of view (e.g. "chat temporal restriction to stop spam" vs "encouraging reflection to stop spam via supportive communication"). Thus, integrating the SDT instruments in the HCD process can become a first step to detect well-being issues within the learning technologies as well as help formulate informed design decisions. Moreover, leveraging SDT instruments in iterative design ensures sustainability and continuous improvement in the Human-Centered Design (HCD) cycle.

5.2 Limitations

While this study provides valuable insights into the integration of well-being in design processes, it is important to acknowledge certain limitations.

The first limitation pertains to the sample size. Even though the quantitative methods used in the proposed co-design process do require a small sample to be manageable (i.e. focus groups) [72], the small sample size utilized in our study may have influenced the ranking of tool features and stress-related findings, especially regarding the sustainability and scalability of future work. Therefore, focus groups would have benefited from more participants (e.g., 6-10 per group). Similarly, the quantitative methods' (i.e. SDT scales) sample size (n=21) could have also benefited from a larger sample. Of the 21 participants in this last sample, 20 were new students; only one had participated in prior design phases (Ideation and Evaluation). We acknowledge that a fully unbiased evaluation ideally excludes repeat participants from previous design phases.

The second limitation refers to the coding method. Only the first author participated in the coding of the qualitative data, with the main reason being that the data collection process itself facilitated partial coding (i.e. students were asked to evaluate each functionality and give its pros and cons). The second part of the coding also required no major thematic classification, since it is based on the three BPNs. Nonetheless, we acknowledge that this could be seen as a limitation, and a second coder would be ideal for ensuring coding reliability of results in future iterations.

The third limitation pertains to the design implications. One of the design implications connects to experiences happening outside the tool and that are not strictly reflected in the technology experience of the students: environmental effects. These potential environmental effects, also reported in research [73], might be connected to classroom dynamics, actions or discussions happening outside the digital environment of the tool. Therefore, the BPNs evaluated in this work might not necessarily reflect these aspects in the results, which calls for further work on the tweaking of the SDT instruments used to evaluate digital learning environments, to also consider said environmental effects.

The final limitation concerns the evaluation method itself. Since it was conducted solely with a non-functional high-fidelity prototype, the perceived BPN might not fully reflect real-world impacts. While this approach demonstrated the work's low-resource usage, it also means the evaluation represents only a first iterative phase. Therefore, future iterations should involve expanding the evaluation to fully functioning prototypes to capture more accurate, real-world user perceptions.

6 Conclusions

To conclude this work, we highlight the three main contributions as well as remark some considerations, limitations of the design process and outline directions for future work. The first contribution is a clearly defined methodological framework, outlining a structured format for SDT-based co-design and a corresponding data analysis approach. The second contribution is the illustration of this process through the evaluation and redesign of a real CSCL tool (PyramidApp), offering a step-by-step design process. The third contribution is the development of well-being-informed design implications based on students' perceived BPN fulfillment.

The tool presented in this paper incorporates features common to other CSCL and learning technology tools. We found that designs based on student proposals, when tested in a controlled prototype setting, resulted in higher perceived BPN satisfaction compared to the previous tool design. This positive outcome encourages broader application in real-world environments, opening pathways for future research. Applied in practice, this could potentially lead to both improved learning experiences, a heightened sense of well-being, and offers valuable design implications for similar tools. Additionally, the findings demonstrate that involving students directly in the design process leads to more effective development of well-being-focused digital tools that address students' specific needs and frustrations. The replication of the proposed co-design process can be beneficial not only for the development of other CSCL tools but also for TEL in general. Despite some limitations, such as sample size and the number of coders, the significant results obtained through the design process support the potential of this methodology.

For future work, we propose three main considerations: (1) Further research into environmental factors (non-specific to technology use) and their connection to BPN fulfillment during the learning experience with the technology, (2) implementing the redesigned features in a real educational context, evaluating the real-world impact of such interventions on students learning experience and well-being and (3) replicating the design process with a larger sample.

Acknowledgments. This work was supported in part by PID2023-146692OB-C33 funded by MCIN/AEI/https://doi.org/10.13039/501100011033, the Ramón y Cajal programme (P. Santos) and ICREA under the ICREA Academia programme (D. Hernández-Leo, Serra Hunter). We acknowledge the use of Gemini in refining our manuscript's linguistic accuracy.

CRediT author statement. [Khadija El Aadmi-Laamech]: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. [Patricia Santos]: Writing – review & editing, Supervision, Funding acquisition. [Davinia Hernández-Leo]: Writing – review & editing, Supervision, Funding acquisition.

Conflict(s) of interest. The authors report no conflicts of interest.

Data availability statement. Data will be made available on request.

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