1234: INFORMATION TECHNOLOGY FOR SOCIAL GOOD

The design of *Tecnico GO!*: catering for students' well-being during the COVID-19 pandemics

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Abstract

Transitioning to and through University is a delicate period for students' well-being. More-over, the recent COVID-19 pandemic added a further toll through the various challenges related to studying, socializing, community-building, and safety. These challenges inspired the design of a mobile application, called *Tecnico GO!*, to support university students' well-being and academic performance. This paper presents the design rationale and evaluation of the app conducted during the academic year 2021-2022. Findings cluster around three themes: i) students studying needs; ii) building a sense of community; iii) gamification strategies. The discussion elaborates on the student's perceptions of well-being during pandemics. Students' perception of the app is positive, appreciative of the crowdsensing features, supporting learning goals, community building, and safety. On the other hand, the gamification features, as currently deployed, do not achieve the expected goals.

1 Introduction

COVID-19, identified in China in December 2019, was quickly declared a pandemic. Since its outbreak, many countries have adopted a strategy of intermittent lockdown periods in order to curtail the spread of the virus. The lockdown periods have created a paradigm shift in how society conducts itself, affecting individuals, the community, and businesses alike, and causing unprecedented impacts on all aspects of society [48]. In addition to the social

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and economic consequences of the pandemic, years of imposed social distancing and other necessary restrictions have caused widespread impacts on communities' and individuals' physical and mental well-being [7, 52]. In Europe, well-being indicators dropped to unprecedented levels compared to the last 40 years [1]. As highlighted by [56], the COVID-19 pandemic impacted people physically, psychologically, and socially [3]. Furthermore, the forced seclusion generated new routines, from remote socializing to remote working, learning, and education. Effects from these routines had a noticeable environmental impact [50], promoted inclusion and accessibility, and are likely to continue in the long term. Additionally, in our globally connected society, pandemics have become an increased risk compared to the past. As COVID-19 was receding, the World Health Organization was already alerting us about another virus commonly called Monkeypox [49].

In the spirit of learning from the COVID-19 lessons, this article reports on the design and evaluation of an app conceived to cater for student academic life and well-being during the pandemic lockdowns. A human-centered design approach was adopted to better understand the students' needs and explore solutions in the context of the university campus and its day-to-day occupation. The research started with an initial survey conducted in October-November 2020 with the participation of 225 students. Results showed that while the majority of students were still coming to campus (self-study, lab classes, and exams), they were missing a sense of community and the social aspects of everyday life on campus, such as study groups, lunches, and coffee breaks, informal chats with colleagues and professors [38].

These results from the survey motivated the researchers' team to find a way of serving students during this challenging period and helping them to re-create a sense of community and safe proximity. With this in mind, the researchers designed *Tecnico GO!* a crowdsensing-enabled service working to promote students' well-being during the COVID-19 pandemic. The app supports students in a number of ways: i) helping students be aware of occupancy and crowdedness of specific spots on campus through passive Wi-Fi and crowdsensing-enabled map; ii) monitor spaces occupancy and facilitating booking of safe study rooms and library spaces through an intent-booking mechanism; iii) gamification strategies to support community building [38].

In this paper, we present the results of a case study focused on how Tecnico GO! caters to students' well-being in terms of supporting safe group studying on campus, socializing, and community engagement during the pandemic. Firstly, we present a preliminary evaluation (N=8) focused on gamification, which results inform the final app design and implementation. Then, a presential evaluation study (N=12) conducted in November 2021 asked students to perform several basic tasks on the app and reflect on them while looking back at the past academic year. We conclude by discussing the results and proposals for future implementations that consider the constant changes of the current pandemic situation.

2 Related work

In this section, we present work related to the design of our application from several angles: first, we analyze mobile apps related to the COVID-19 pandemic with a particular focus on apps for academic settings. Second, we discuss research that aims to understand, support, and foster students' well-being during social distance restrictions. Third, we present and review gamification as an engagement strategy; Fourth, we present an overview of how gamification affects crowdsourcing mechanisms. Finally, we summarise the related work section, reflecting on how did we extend it while designing our application.

2.1 COVID-19 apps

Smartphone applications, especially those related to contact tracing, symptom monitoring, quarantine support, and information provision, have been crucial in the fight against the COVID-19 pandemic, as indicated by multiple surveys. Collado-Borrell et al. analyzed N=107 apps in Western languages, concluding that the most common objectives were: providing general information about the virus (n=66, 64%), COVID-19-related news (n=53, 51%), recording symptoms (n=53, 51%), and contact tracing (n=51, 47.7%), with n=99 (92.5%) of the apps involved in more than one purpose [13]. Ming et al. reported that more than half the apps analyzed (total N=223) were providing information from and to the health authorities: tracing or mapping (n=18,37.5%), and home monitoring surveillance (n=15, 31.3%) [43].

The most discussed type of apps related to COVID-19 are likely the ones designed for contact tracing. One such example is the Trace Together app created by the Singaporean government, which utilizes Bluetooth technology to monitor individuals and, in the event that they report being infected, alerts those who have had recent contact with them [10]. The efficacy of contact tracing apps is largely contingent on whether people choose to use and embrace them, but in numerous countries, their adoption rates have been quite low [58]. Additionally, many of these apps lack clear information regarding how they collect and handle data and grant limited user control and rights with respect to this data, resulting in concerns regarding privacy, data protection, security, and personal freedom [55]. Due to the widespread failure of such apps to gain traction, we opted instead to use passive Wi-Fi technology, which is sensitive to privacy concerns, to track the number of users in a given space by counting the number of devices while still safeguarding their personal information [51].

In the initial two years of the pandemic, there was a proliferation of apps designed for students, with a particular emphasis on facilitating safe attendance on campus. The safe resumption of in-person classes has been a crucial issue for many universities. These apps' focus varies from contact tracing (e.g., [61]), self-report (e.g., [60]), campus pass (e.g., [22]), showing vaccination status (e.g., [9]) or check-in QR codes (e.g., [34]). Nevertheless, these apps have not been exempt from worries related to safeguarding personal data and maintaining privacy [17].

As far as we are aware, these apps have displayed similar design approaches and have not pursued a comprehensive design strategy that fuses technology-based resolutions with a focus on student well-being. We address this void by creating and assessing a socially conscious student app. Our goal was to give students the power to make well-informed choices that can enhance their study habits while also ensuring their safety and privacy in light of technological concerns surrounding data protection.

2.2 Well-being in times of social distancing

Due to the urgency of altering our social habits in order to protect our healthcare systems during the COVID-19 pandemic, we were forced to rapidly implement dramatic changes to our daily routines. At various levels, these measures included social distancing and further restrictions that caused discomfort, shock, and a decline in overall well-being. This had an impact on various aspects of our lives, such as our physical activity, sleep, and dietary habits, among other factors [52].

Numerous studies have emphasized the harmful psychological ramifications of quarantine measures, including but not limited to post-traumatic stress symptoms, anger, confusion, frustration, and boredom, while also suggesting the possibility of long-lasting effects [8].

These novel stressors, arising or intensifying due to the pandemic, span from psychophysiological factors to social and work-related ones, all of which directly influence the mental health of the population [11].

The social relationships of young individuals are of paramount importance and greatly shape their perspective on the world. The abrupt restrictions imposed by the pandemic had an adverse impact on their psychological well-being [17, 42]. Nonetheless, the impact of the pandemic on younger individuals was not uniform. Those who were already doing better before the pandemic, and had greater resources at their disposal, continued to fare better - the pandemic merely exacerbated pre-existing inequalities [30]. During the pandemic lockdown, students were forbidden from congregating and socializing on campus, which had a significant impact on their daily lives. For younger individuals, adhering to a routine is crucial as it provides opportunities for social interaction and a sense of belonging [36]. Routines serve as crucial psychological resources, particularly during times of uncertainty and stress [41]. Feeling socially connected during the pandemic has been helpful in reducing anxiety and depression [39]. Therefore, it is important to foster a sense of community and facilitate safe proximity to support the well-being of younger populations, including university campus communities.

A previous study [38] points to how students suffered from social distancing, which kept them from participating in their university community life. The authors noted that students expressed their dissatisfaction with the lack of opportunities to participate in study groups, learn from their peers, and be inspired by their mentors during casual encounters. Students also mentioned feeling lonely and fatigued with their home setting and reported that they were more productive and focused while on campus. Mental health was a common concern among the students as well. With this in mind, we aimed to gain a better understanding of our student population's previous and current well-being to inform the design of an app that meets their needs.

2.3 Gamification and gamification frameworks

Gamification is a diverse strategy employed to influence motivation and engagement [24]. Deterding et al. ([16], p. 9) defined gamification as "the use of game design elements in non-game contexts" to make an experience more enjoyable, motivating, and engaging. While Hamari et al. view gamification as an umbrella term for the motivational affordances (game elements) designed to invoke psychological outcomes which lead to behavioral outcomes [24].

Gamification frameworks are formalized methodologies to help designers decide what game elements to employ to serve their purposes better. These frameworks consider the desired outcome, the context of the gamification, the users the designer is targeting, their business objectives, etc. There is a myriad of available frameworks, tested for different metrics and developed for different outcomes. Both academics and enterprises develop gamification frameworks to formalize their gamification strategies. A review by Mora et al. [45] identifies the most common design framework as the Six Steps to Gamification by Werbach and Hunter [62]. This framework divides the process into two points of view - i.e., the organization deploying the gamification strategy and the users. The framework starts with a definition of business objectives and the prioritization of goals. The framework then proceeds to target behaviors to be gamified, describes the players (users), devises the activity loops and progression stairs, and suggests product research before formalizing the strategy in terms of elements. The framework suggests an iterative, user-centered approach to formalizing the

end product. The framework is partly inspired by Hunicke et al.'s Mechanics, Dynamics, and Aesthetics (MDA) game design framework [28], where a hierarchical pyramid exposes the relationship between dynamics, mechanics, and aesthetic components - MDA forms the latter portion of the Six Steps to Gamification framework.

Gamification is a contentious subject in both research and industry. There is debate about whether gamification is effective, whether it is ethical, and about the outcomes [24, 29]. There are many studies demonstrating the efficacy of gamification [26, 27, 32, 47]. However, several reviews have identified a number of mixed and sometimes negative results [24, 35, 53]. Authors of studies with negative results suggest that context is an important factor [25, 44, 57]. It has been suggested that extrinsic rewards undermine intrinsic motivations [14]. Some studies have suggested that gamification can be a novelty and leads to a short-term impact only [19, 25]. Studies have found that gamification negatively impacts the quality of work, with users rushing activities to get their rewards [29]. The ethics of gamification is well discussed in the literature. Gamification has been deemed as "exploitation ware"- A view that gamification is distorted behavioral economics strategies masked by game design elements [5] is contrasted by Kim and Werbach [33] arguing that gamification itself is not exploitative, manipulative or harmful.

Some studies suggest that gamification can be addictive, atomistic, and deterministic [12, 15]. Marczewski provides the example of the Sesame Credit social credit system rolled out by China, used to score citizens based on their behaviors [40]. Gamification can elicit poor personal characteristics in people [54] with users performing only for their own reward [29]. However, there are several positive gamification studies. Education and health and wellness are two sectors that seem to benefit. Hamari et al. found that gamification increased students' enjoyment of and engagement with educational activities in several studies ([24]). Seaborn and Fels found only positive reports from their health and wellness gamification studies analysis [53].

2.4 Gamification in crowdsourcing

Crowdsourcing systems are some of the most researched areas in the context of gamification [24]. The research can be divided by what form of crowdsourcing the gamification has been applied to, which are: crowd processing, crowd rating, crowd solving, and crowd creating. Two reviews by Morschheuser et al. have aggregated the studies on gamification strategies employed in different types of crowdsourcing [46, 47]. These reviews provide recommendations on three of the four types of crowdsourcing based on the frequency of applied gamification elements and their perceived success. Crowd processing, which seeks homogenous non-emergent contributions, tends to reward the fulfillment of the completion of some tasks. Gamification elements such as points and leaderboards are usually combined to foster competitive engagement amongst participants [31]. Crowd rating, which seeks homogenous emergent contributions, is usually employed to gain votes on a given topic. Thus, the quality and the quantity of the contributions in the case are important. This type of crowdsourcing often sees points and leader boards employed, less often with combinations with badges and achievements, levels and rewards [46]. The employment of simpler gamification strategies works well for both crowd processing and crowd rating [18]. Crowd solving seeks heterogenous non-emergent contributions and is thus diverse and difficult to value. Crowd-solving studies have demonstrated a diverse approach to rewarding participation- With points, leader boards, badges/achievements, levels, progress, feedback, and rewards. Storytelling, missions, and virtual territories are all studied as motivational gamification elements. Furthermore,

rewards based on the quality of the contribution are recommended [46]. Crowd creating seeks heterogeneous, emergent contributions, in other words, diverse and creative contributions. A small number of empirical studies on the topic have used various gamification elements.

Our application adopted the first two types of crowd engagement, namely crowd processing and crowd rating, engaging users in participating through a simple gamification strategy: assigning points to those who contribute and keeping track of contributors' engagement through leaderboards. More complex gamification strategies involving positive feedback and storytelling were designed but not implemented or evaluated because of timing and funding issues.

3 Tecnico GO! design and implementation

In this Section, we first present the research questions that drove our research. Then, we describe the preliminary evaluation performed to evaluate the gamification mechanisms we implemented to engage students in exploring and contributing to the app. The Section continues by presenting a general overview of the app and its features. Finally, we describe the protocol adopted in the final evaluation to situate the user study's goals.

3.1 Research method

The design and development of Tecnico GO! underwent several stages as the app design adapted to the dynamic changes and restrictions imposed by COVID-19. The app implementation builds on the human-centered and service design approach to design for students' needs during social distancing [38]. The present study extends on [37, 38, 59] and aims to evaluate the students' acceptance and reactions to these functions. Moreover, the authors wanted to explore future development for the app and its possible adaptation to post-pandemic use. To investigate the above, the study was guided by the following research questions:

RQ1: How does Tecnico GO! perform in terms of catering to students' needs during the COVID-19 pandemic (studying, socializing, community, safety)?

RQ2: How might alternative features help foster students' well-being during/after the pandemic?

To answer such RQs, two different evaluations have been performed: i) a preliminary evaluation, exploiting interactive wireframes whose outcome informed the design and implementation of the gamification strategies; ii) a final evaluation where students were engaged in using the release version of Tecnico GO!.

3.2 Preliminary evaluation

To present the preliminary evaluation, we first describe the protocol, then the participants, and finally, the resulting findings.

3.2.1 Protocol

The preliminary evaluation was performed in 2021. Due to the COVID restrictions and the period of uncertainty, we prefer to preserve participants' safety, avoiding engaging them in live sessions on the campus premises. To overcome this issue, we exploited two software: Figma[1] to create interactive high-fidelity wireframes and Maze[2] to create an interactive online questionnaire. Using Figma, we created the app screens with a high level of detail (i.e. high-fidelity wireframes, see Fig. 1). Then, we created a questionnaire exploiting the Maze functions. The main objective of this preliminary study was to evaluate the gamification mechanisms we put in place to engage students in exploring and contributing (with crowdsourcing) to the app.

The questionnaire comprised 46 blocks; each block defines a single task that the user has to perform. By completing the task, the user can simply answer a question (e.g., yes/no, multiple answer question) or can interact with the wireframes to reach a specific goal. The 46 blocks include: the first one required for the consent; four personal questions (age, gender, status, university program); six informative or context screen blocks (i.e., no action required); six multiple answers questions; eight yes/no questions; eight prototype testing blocks; six opinion scale questions (Likert scale from 1 to 11); seven open questions. For more details, see Fig. 2.

Exploiting the content screen and the prototype testing blocks, we created a storyline about a possible interactive session with the app. We simulated a session, starting with the login into the app. During the session, each driven action allows the user to explore the Tecnico GO! function and enjoy the gamification strategies. For example, by clicking the login button, the participant can progress to the next block, where the system shows the home page and a pop-up explaining that, through this action, the user has just earned 50 points. The points are called experience points - XP points - inside the app to reinforce that the more the user masters the app and its functions, the more points s/he gains. Other blocks require more actions from the user. For example, in a block, the system challenges the user to find other ways to gain points. In such a case, the user can freely interact with the Figma high-fidelity wireframes and explore the app. Additionally, with the content screen, the participant can read relevant information and visualize static screens, such as the badges screen with a new badge unlocked as a consequence of a previous task. Thanks to the created storyline, the participant can try all the app functions through the Maze questionnaire and experience the gamification mechanisms as in a live session (Fig. 2).

3.2.2 Participants

We invited students to join our evaluation by sending a message through a course forum (held by one of the authors); twelve students answered our call for interest, and eight successfully concluded the questionnaire. Participants (five males and three females) were in the age range 19-30, with the majority in the range 22-24. All participants were attending a Computer Science program: five a Master's Degree, one a Bachelor's Degree, and one a Ph.D. program.

To situate the participants' attitudes, we asked them whether they had physically attended university since the term began. Half of them didn't, two of them attended only the current
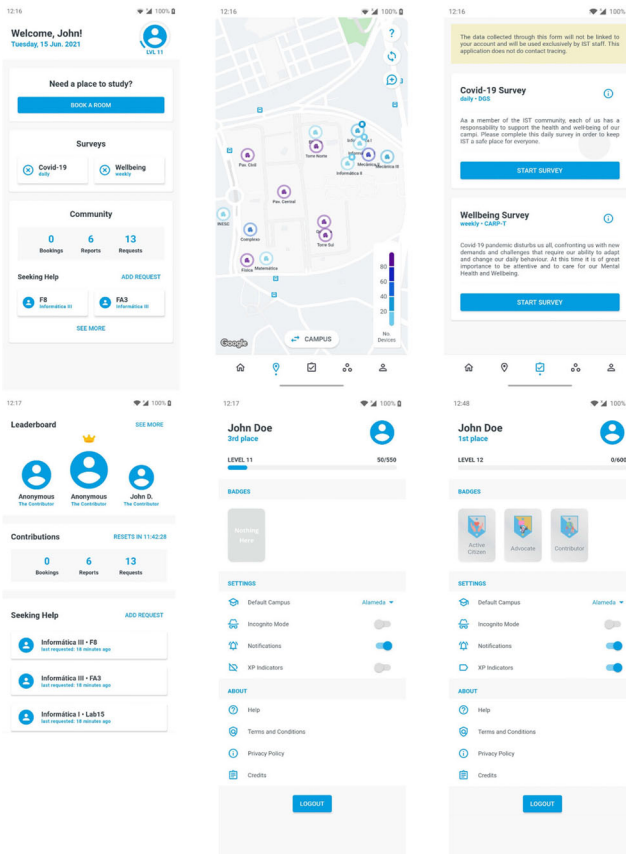

Fig. 1 Selection of some high-fidelity wireframes used in the interactive questionnaire, from left to right, top to bottom: i) home page; ii) campus map; iii) survey; iv) user profile; v) leader board; vi) user profile with unlocked badges

week, and two since the term began. Additionally, we asked them if they were looking forward to being back on campus on a regular basis, and six out of eight answered positively.

In order to better understand their game attitude, we also asked participants about their player type (i.e., achiever, killer, explorer, socializer - [2]) and player lifecycle/skill level (i.e., novice, regular, expert - [62]). Table 1 briefly describes each player category. Most participants define themselves as achievers (four out of eight), two as killers, one as an explorer, and one as a regular.

3.2.3 Findings

The findings are here summarized by analyzing the different gamified functions, considering both the general questions (i.e., open, yes/no, and multiple answer questions) and the data collected on each prototype testing block (such as the number and position of the clicks) while the user was interacting with the high-fidelity wireframes.

#	Blocks	Type
1	Consent	Yes/No
2	Have you physically attended university since this term began?	Multiple Choice
3	Are you looking forward to being back on campus?	Yes/No
4	How would you describe yourself when playing a game?	Multiple Choice
5	Login Tecnico Go!	Prototype test
6	Enable XP (Experience Points) Indicators	Prototype test
7	Would you prefer to enable the XP indicators?	Yes/No
8	Updating your progress	Context Screen
9	Explore	Prototype test
10	How many ways did you see/find to get points in these five screens?	Open question
11	Which ways did you find more interesting?	Multiple Choice
12	One way of winning points is by answering one of the surveys that "Tecnico Go!" offers.	Prototype Test
13	Updating your progress	Context Screen
14	Would you enjoy getting points by filling out surveys?	Opinion scale
15	In your opinion, is it (Surveys) useful?	Yes/No
16	Why do you think it (Surveys) is not useful?	Open question
17	Request Feedback	Prototype Test
18	Updating your progress	Context Screen
19	Would you enjoy adding requests to know the occupancy of a classroom to help you plan your visit to campus?	Opinion Scale
20	In your opinion, is it (Request Feedback) useful?	Yes/No
21	Why do you think it (Request Feedback) is not useful?	Open question
22	(Intent) Booking	Prototype Test
23	Updating your progress	Context screen
24	Would you enjoy using intent-book before visiting the campus?	Opinion scale
25	In your opinion, is it (Intent-Book) useful?	Yes/No
26	Why do you think it (Intent-Book) is not useful?	Open Question
27	Report Feedback	Prototype test
28	Updating your progress	Context screen
29	Would you enjoy voluntarily reporting the number of people in different areas on campus to help the community of the App?	Opinion scale
30	In your opinion, is it (Report Feedback) useful?	Yes/No
31	Why do you think it (Report Feedback) is not useful?	Open question
32	Check your leaderboard	Prototype test
33	In your opinion, is it (Leaderboard) useful?	Yes/No
34	Why do you think it (Leaderboard) is not useful?	Open Question
35	Would you enjoy using the various features of "Tecnico Go!" through these playful ways you experienced?	Yes/No
36	Which ways make you enjoy "Tecnico Go!" ?	Multiple Choice
37	Which ways makes you not enjoy "Tecnico Go!"?	Multiple Choice
38	How would you describe yourself when using "Tecnico Go!" ?	Multiple Choice
39	Do you think these gamification strategies can motivate you to engage with "Tecnico Go!"?	Opinion scale
40	Would you recommend "Tecnico Go!" to your classmates, friends, and other members of the IST community?	Opinion scale
41	Do you have any suggestion to "Tecnico Go!"?	Open question
42	Additional Information	Context Screen
43	Are you a student, teacher, researcher or expert?	Multiple Choice
44	In what IST course/program are you enrolled?	Open Question
45	Age	Open question
46	Gender	Multiple Choice

Fig. 2 The 46 blocks included in the interactive online questionnaire

Focusing on the survey function, we asked participants if they enjoyed using it and gaining points. On a scale from 1 (would rather not) to 11 (would extremely enjoy), three users selected 11, one selected eight, one selected six, and three selected five. Contrariwise, seven out of eight students found the survey helpful. The one (that we call *student X* to identify him/her) who disagreed motivated the answer: "They are not always useless, but in this case, the survey about COVID-19 symptoms I think it's useless because everyone knows that they should stay at home if ill, so if someone with symptoms is in the campus would probably lie". Considering the interaction with the survey screens, the interaction was fluent, and no usability issues were reported.

When asked about the possibility of adding requests to know the occupancy of a classroom to help to plan a visit to campus, five students liked it (choosing 11 or 10), one chose eight, and two selected negative values (five and one). Also in this case, seven out of eight found the general function useful. The one (student X) who answered negatively didn't understand the motivation behind the feedback function; nonetheless, also this user was able to interact with the screen successfully.

The intent-book function was enjoyed by seven users (five chose 11, one chose 10, and one chose nine). Also this time, we have one not satisfied student (student X) who voted three

Table 1 The different player categories with the related definition

Categories	Definition
Achievers	who need a sense of progression and accomplishment
Explorers	who want to explore your world and learn
Socializers	who want to connect with others who are like minded
Killers	who thrive on competition and rank
Novices	who need initial step by step help (on-boarding)
Regulars	who need novelty and newness to keep playing
Experts	who need challenges and status reinforcement

and who declared that the function is not useful. The user claimed that "I generally don't make plans. Just go and see if it is full".

Regarding the feedback function, we asked participants if they would enjoy voluntarily reporting the number of people in different areas on campus to help the community of Tecnico GO!. Not surprisingly, seven users reported a positive attitude towards this function (three chose 11, two chose 10, one chose 9, and one chose 7), while a single student (student X) gave a negative feedback of 2. Again, student X didn't find the function useful and claimed "I am afraid very few students will do this and because few do it, it quickly becomes outdated".

We also made users interact with the leaderboard. The interaction was smooth; in fact, also in this case, all participants completed this task via the expected path. Nonetheless, all but one found it useful; the user (student X) who answered no claimed "I find it enjoyable but not necessarily useful".

Finally, we asked users some general questions about the gamified experience. When asked "Which functions make you enjoy Tecnico GO!?" (multiple answer question), the users chose: Booking a classroom to study (six users); Reporting the occupancy of a classroom (six users); Requesting feedback for the occupancy of a room (four users); Catching up with peers on the leaderboard (four users); Enjoying the progression of level up (three users); Collecting various badges (two users). Contrariwise, we also asked them what they did not like. Four users declared not to like filling out the surveys about the COVID-19 pandemic; one didn't like the possibility of collecting badges. We also asked if they think the presented gamification strategies can motivate them to engage with Tecnico GO!. Most of the users answered positively (five chose eight, and three chose 11, the maximum positive value); as expected, one user (student X) chose a slightly negative value (five). Similar is the outcome of the questions: "Would you recommend Tecnico GO! to your classmates, friends, and other members of the IST community?". Finally, we asked for open comments. A student claimed: "I would avoid to make Tecnico GO! mandatory because some students may not consent to install it. I can imagine a future where students are forced to "check in" to class with the app, otherwise, they fail the course. And that will be a very sad future."; and continues "I also think that gamification can be a powerful motivator to keep using the app. Those (like me) who are not motivated to have it in the first place, it won't do much". Another student, instead, left a very positive: "The app looks really promising! I can't wait to try it!".

To conclude, this preliminary evaluation emphasized that the app is, in general, usable and clear. The gamification strategies are, for most of the users, interesting and enjoyable. Nonetheless, some refinements can improve the experience since, if not guided; the users

seem to have some difficulties in finding the gamified functions. These findings informed the design and implementation of the final app.

3.3 Development of the app

The app was deployed based on an original service blueprint describing a complex service conceived for students during the COVID-19 pandemic [38]. A partial implementation of the blueprint is deployed in Tecnico GO! and gives form to the basic features of the mobile application. The deployment efforts were interdisciplinary, with contributions from HCI researchers, gamification and service designers, and back-end and front-end engineers. The app is currently in its Beta version and was uploaded on Google Play and TestFlight - it is accessible exclusively through an invitation. In its current deployment, the app is functioning only for students who access the campus. The Beta version includes the following primary features: i) Map; ii) Intent booking and room occupancy feedback; iii) Gamification strategy and community (see Fig. 3). More details about the implementation of each function are presented in [59].

   The Beta version includes the following primary features:

   i) **Map** (Fig. 3.2 and Fig. 3.3): The campus map contains three layers of information: i) the location of the Wi-Fi sensing technology (router) on campus; ii) the number of devices detected by the Wi-Fi routers at any specific location (where and when the router is available), presenting the real-time traffic and history trends; iii) the occupancy data, which is a result of the passive sensing and the crowdsensing mechanism. The granularity of the data ranges from zone to room occupancy, and the accuracy from devices number to foot traffic accuracy. Crowdsensing data is composed of two parts: intent booking and feedback.
   ii) **Intent booking** (Fig. 3.1) and feedback: Students can let the system know of their intent to travel to campus via intent booking or give feedback on room occupancy (see Fig. 3.1 and 3.3). These two features help the system to predict foot traffic and benefit students' decision-making.
   iii) **Gamification strategy and community** (Fig. 3.4): the Beta version deployed the leaderboard and badges placeholders in the community page. This page includes: i) the leaderboard that covers all registered students and displays students' names, photos, badges, and levels (level up by accumulating points from rewarded activities); ii) the contribution board that shows the daily counts of all activities (bookings, reports, and requests); and iii) the list of help requests, in particular regarding specific rooms occupancy estimation.
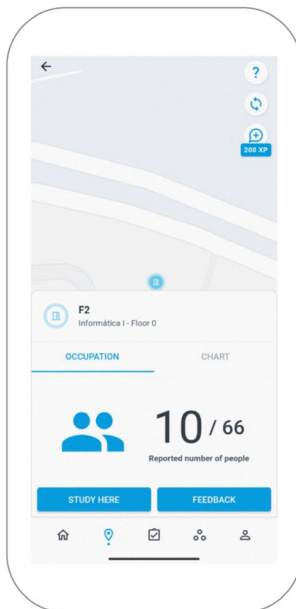
3.4 Final evaluation protocol

This Section details the information about participants, researchers, and resources involved in the study, including details about the interview procedure. The outcome is then presented and discussed.
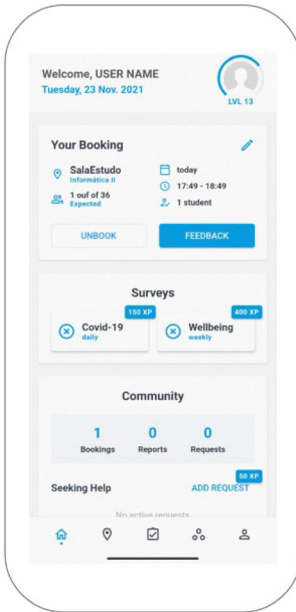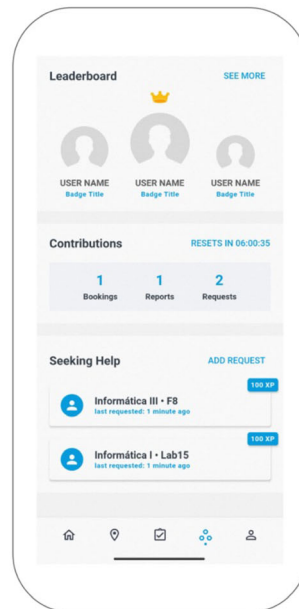
1) Intent book
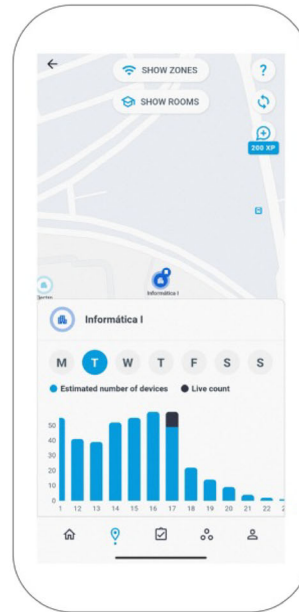
2) Campus Map: Buildings

3) Campus Map: Rooms

4) Community

Fig. 3 Selection of the main features of the app Interface: 1) Intent booking page; 2) Campus Map; 3) Classroom booking and occupancy projection; 4) community and gamification features

3.4.1 Participants, researchers, and resources involved in the study

The evaluation protocol was based on semi-structured interviews, a think-aloud protocol, and a final Likert scale survey. The protocol was designed as a collaborative effort between all authors and conducted by two researchers (the second and third authors) in a lab-like condition: a room with a table and a mobile device with the app installed at the disposal of the participant; researchers would record the device screen, the interview, and take notes during the participants' performance of the tasks. University students enrolled in the 2020-2021 academic year were recruited via snowball sampling, inviting them to recommend other colleagues to grow our set of participants (N=12). The average length of the study was 35 minutes.

3.4.2 Interview procedure

First, the researcher welcomed the participant, explained the study, and signed the agreement. Second, the interview started with eight questions to set the context of their experiences during the academic year 2020-2021. These questions focused on the modality of classes they experienced. Third, the participants were asked to perform three sets of tasks in the app, adhering to a "think-aloud" process of evaluation. This process was organized through the presentation of a series of usage scenarios, asking participants to finish the tasks on the mobile device and comment out loud on their actions and impressions. Three sets of tasks covered all functions deployed in the app: intent booking, navigation of the campus through a customized map, feedback, and gamification features. Subsequently, we finalized the study by discussing the app's impacts in relation to studying, socializing, community, and safety needs. Finally, to counteract the possible bias and pleasing effect of the in-person interviews, we surveyed participants' satisfaction with the app features. The survey consists of nine Likert scale questions (Fig. 6.1) and one multiple-choice question (Fig. 6.2). In the next sections, we describe the findings in detail, discuss them and illuminate the path for future work.

3.4.3 Data collection and analysis

The third and fourth authors transcribed and initially analyzed the interviews and think-aloud protocol data through grounded theory and thematic analysis [6]. The results were revised by them and discussed with the first author. Divergences were clarified, and findings were debated and finalized. Lastly, the Likert survey results (Fig. 6) were discussed in relation to the qualitative findings.

4 Findings

In the following Section, we report the findings from the final evaluation, composed of the semi-structured interviews, the think-aloud protocol, and the survey. The findings were then arranged, reported, and discussed in the context of the interaction with the application according to the annotated portfolio methodology [23]. The app wireframes presented to

the users were annotated with the observations extracted and concluded from the semi-structured interviews. Figure 4 visualizes the annotated portfolio document in which the findings were organized and which formed the basis for the discussion. The findings were organized around four main themes that emerged coding and elaborating on the collected data: i) student's academic experiences during the pandemic; ii) the app as a support for the study experience; iii) Crowdsensing and sense of community; iv) gamification strategy, leaderboard, and competition. We present the findings in detail below.

4.1 Student's academic experiences during the pandemic

The first section of the interviews focused on students' experiences regarding the learning modalities (online and/or in-person) and overall academic life during the pandemic. The results have been compiled in the visualization presented in Fig. 5. Most students (n=9) appreciated the online teaching aspects of the last academic year (2020/21) for their practicality and for allowing better time management. Two students mentioned appreciation for the lectures being recorded. One student mentioned that they felt more focused with this modality, while four others highlighted difficulties in focusing and in clearly understanding colleagues or instructors. Most interviewees (n=10) felt alone, missed being with their colleagues in person, or felt online classes were impersonal. The balance of positives and negatives of online classes - practicality versus lack of connection with colleagues - was a recurring theme. Regarding presential attendance during the academic year (2021/22), students reported mixed opinions. Four students felt in some way uncomfortable when attending

Fig. 4 The screenshots of the interfaces presented to the users were annotated with the observations extracted and concluded from the semi-structured interviews
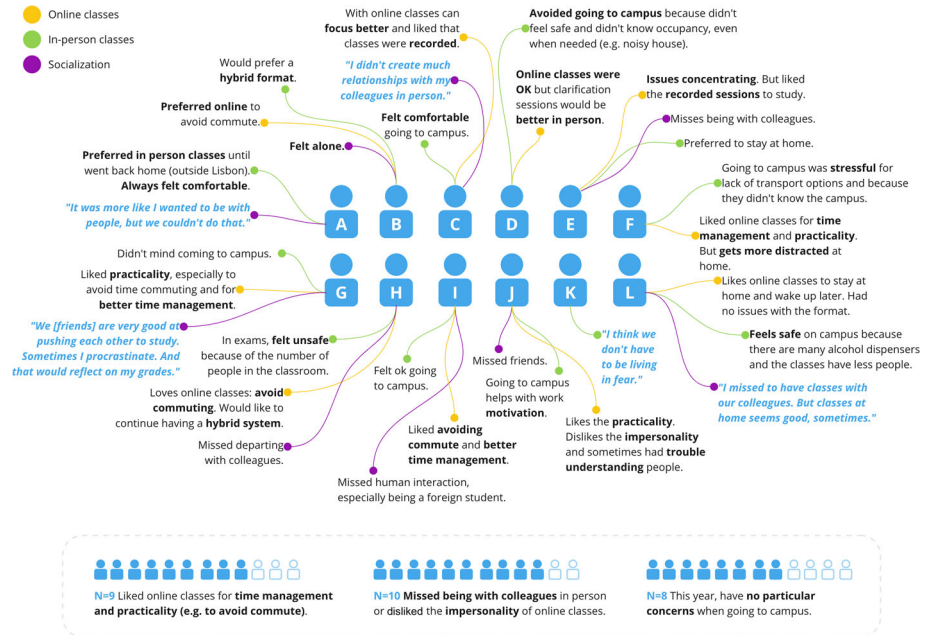
Fig. 5 Student's perceptions about online and in-person classes and well-being during the pandemic (2020-2021)

classes or labs in closed spaces - e.g., lack of social distancing or because of the unsafety connected to using public transportation during the commute. Nevertheless, the majority (n=8) have no particular concerns about going to campus.

4.2 Supporting the study experience

In the interviews, all participants (N=12) reported the app being helpful because of the intent-booking, map, and room occupancy features. Participants found the Intent booking and room occupancy features useful in finding a safe place to study (not overcrowded) (N=10). The main reasons for using these features would be saving time, safety (avoiding crowded places, keeping social distance), as well as organizing study sessions alone or with colleagues. Most students mentioned the app could support study groups by checking the room occupancy and booking an empty room (N=7). Interestingly, three students deeply appreciated the map (independently from other features) because of the lack of familiarity with the campus facilities. In general, students valued the app's support in times of pandemics and would find it useful in the present and future as well. Lastly, students' responses from the Likert scale data show that all of them would agree to use the app to guide their campus visits (Fig. 6.1) and to organize personal and group study through the intent booking features (Fig. 6.2). Meanwhile, students showed their preference through the multiple-choice question: booking is the most welcome feature (Fig. 6.2).

1. Students' review in Likert scale about using the App to guide their campus tour (N=12)

#	Likert Question	Mode	Mean	Standard deviation	Average
1	Would you enjoy using the App as an overall reference to guide your trip to campus?	5	5	0.52	4.58
2	Would you enjoy using the intent book before visiting the campus?	5	5	1.27	4.17
3	Would you voluntarily report the number of people in different areas on campus to help the community of the App?	4	4	0.74	4
4	Would you enjoy adding requests to know the occupancy of a classroom to help you plan your visit to campus?	4	4	0.65	4.33
5	Would you enjoy the leaderboard feature in the community?	4	4	0.89	3.67
6	To what degree do you think the App helps you make decisions when studying?	5	5	0.65	4.67
7	To what degree do you believe the App can help you socialize on campus during the Covid-19 pandemic?	3	3	1.08	3.42
8	To what degree do you believe that the App can promote a sense of university community during COVID-19 Pandemic?	4	4	0.94	4.17
9	To what degree do you believe that the App can improve the sense of security during the period of social distancing?	5	5	0.90	4.58

2. Students' choices in what features make them enjoy the App

Rank	What do you enjoy in the App?	Number
1	Booking a classroom to study	11
2	Requesting feedback for the occupancy of a room	10
3	Report the occupancy of a classroom	7
4	Checking the campus map	7
5	The progression of level up and catching up with peers on the leaderboard	4
6	I am not committed to using any of the features	1

Fig. 6 1. Results of the Linkert survey (scale from 1-5) - Using the app to guide campus visits is the major intent, and the leaderboard gets few adoptions; 2. Result from multi-choice questions about their preference on features - Booking and requests are most welcome features, reporting and campus Map are also adopted by most students

4.3 Building a sense of community

We now present the results regarding the three scenarios: i) students can provide feedback on a room occupancy when personally there; ii) respond to the feedback request from the community; and iii) give feedback on any rooms on the map (even if not there at that moment). Most students (N=10) expressed their willingness to contribute feedback in regard to the room they are currently occupying, while two mentioned more incentives would engage them more. After experiencing the app, most students argue that crowdsensing the occupancy of the rooms is a form of helping each other and organizing study groups and contributes to their sense of community at Campus (N=11). One student, on the other hand, lamented that the anonymization of the feedback process contributed to a sense of alienation from their colleagues. Most participants (N=9) mentioned that they would not contribute to requests about rooms they were not in unless they passed by the requested room or had enough spare time to go there and check. Furthermore, two students usefully raised concerns regarding the accuracy of the feedback: i) quality and quantity of feedback depend on the participation rate; ii) issues may arise with false reports and rapid foot traffic. From the Likert scale questionnaire and the multiple-choice question, students also confirmed their enthusiasm to send or report feedback on the room occupancy (Fig. 6). Giving feedback and requesting feedback emerged

as a primary force in creating a sense of students' stewardship, community, and proximity to colleagues.

4.4 Gamification strategy, Leaderboard, and Competition

Regarding the gamification features of the app, five students believe that gamification could motivate and engage people to participate in the crowdsourcing of the data and increase the use and adoption of the app. Four students felt that the gamification features would instigate competition and stimulate action only by expecting a reward and, consequently, were turned off by it. Moreover, when answering the survey's multiple-choice questions, only four students expressed enjoying and valuing the leaderboard feature in the app. Data from the survey showed that most students considered that the leaderboard was not attractive enough (Fig. 6), failing to comply with the Aesthetic demands of the MDA framework, the last of the 6 steps to gamification [28]. Several students highlighted that mindful and consented exposure of private information of the users contributing to the crowdsourcing features could help the gamification strategy and build and reinforce the student's sense of community. Suggestions about adding networks of friends and coursework groups and allowing students to display information (e.g., study status, coursework tasks, faces, and names) were voiced often.

5 Discussion

From the app evaluation, students' sense of well-being emerged as threefold, unfolding concerns related to learning, community, and safety. In the following sections, we discuss students' sense of well-being against these three concepts while assessing the goals of the app.

5.1 Well-being and learning

One of the central purposes of the app was to assist students in their learning tasks, returning to and safely using the campus facilities. COVID-19 safety measures affected students' general sense of well-being and, consequently, their learning experience. Loneliness and alienation affected motivation (Participant G: "… I procrastinate, I would not work as hard. And that would reflect on my grades."), productivity (E: "… it is hard to keep concentrating on the lessons"; J: "…coming here [to campus] makes me want to work more. It has a factor on motivation, for sure.") diminishing focus, especially for those who shared housing or studying spaces (F: "I get more distracted at home."). Physical proximity with colleagues and access to the facilities enhanced the students' academic performance. Students voiced the advantages and disadvantages of online classes (J: "I can be comfortable at home, but it does have the disadvantage of impersonality.") (F: "It was good because we have more power to organize our time"; G: "I could manage my time better. It was very practical."); Hybrid formats of learning seem to be the way forward (B: "But I feel a little alone. I'd prefer to have a hybrid way."; G: "I love having classes online, and I would like to have that same hybrid method."). Students' diversity and preferences highlight the need for personalization of the university system (A: "I want this [in-person classes] to keep being like this."; B: "Prefer to stay at home. I like the idea of not coming and not spending time in traffic."; L: "A mix of the two. I missed having classes with our colleagues. But classes at home seem good, sometimes.").

The COVID-19 pandemic highlighted the need for flexibility to include and satisfy a broad range of students. Solutions can integrate in-person learning, group studies, and face-to-face meetings with the advantages of remote classes and distance learning. Further studies will need to illuminate how to pursue a hybrid practice. According to our study, most participants valued the support that the app provided and suggested that they would still find it helpful in a new-normal situation. The app would help them make decisions and better planning when visiting campus. This would support their academic performance and mental well-being by allowing safe access to resources and supporting the organization of study groups. We are still living through uncertain times, new challenges and viruses keep appearing, and our global societies are increasingly prone to pandemics [4, 49]. Unpredictable renewed restrictions might leave students suddenly isolated again, and having safe access to study and socializing facilities is crucial for their well-being.

5.2 Well being and sense of community

Most of the students interviewed mentioned missing out on in-person gatherings during lockdown (G: "I used to see my friends every single day, and we are very good at pushing each other to study."), feeling alone (E: "... miss the opportunity to meet with my colleagues and talk to them."), and missing out on the university experience (I: "it was missing a bit of human interaction with people because I came from Italy. I didn't have anyone here. I was expecting to have some interaction."). Echoing Deznabi et al. [17], younger generations suffered during the lockdown and lacked the social connections that helped lower anxiety [39]. As pandemic restrictions are eventually resolved, social connection is still valid for vulnerable communities that can be at risk of exclusion and disadvantage in personal and independent displacements. Moreover, for freshmen and Erasmus students, who never experienced life on campus, pandemic safety measures were particularly damaging (F: "I didn't know anything on the campus because it was my first year here."). Students generally expressed a preference for being allowed to decide for themselves to visit campus or not. Some prefer to be with colleagues even when restrictions are in place. Most students found the app helpful in building a sense of community - primarily through the crowdsensing feature (E: "Yes, the feature of helping people on the capacity of the room."; K: "It's this kind of app that incentivizes people to help each other, helping the community."; J: "We are connected very easily through the help and the ask features."); and the support in organizing presential group study sessions on campus (D: "I could study more with my colleagues, and by being on campus, you meet more people."; I: "If I want to gather people to study, I can do that."). Through the survey, most students confirmed the app's potential to create a sense of community but criticized the lack of socializing features, such as the ability to network and make new friends; students lamented the crowdsourcing anonymity features and highlighted the importance of the sense of belonging in times of uncertainty. Overall, the app can assist students in community building. The intent booking and occupancy crowdsensing features promote altruistic social practices as a bottom-up initiative, allowing for a better campus experience for newcomers.

5.3 Well-being and safety

Interestingly, when asked about "concerns related to visiting campus", only three students mentioned COVID-19. Motivations for the concern were: lack of social distancing and crowded rooms (D: "I think we went back to normal a little bit too fast, and we are doing everything as before, just with masks."; E: "The rooms were very full sometimes."). One

student mentioned feeling safer when lockdowns were in place, and people paid more attention to social distancing (C: "we can see classes sometimes full of people, and you cannot have a safe distance."). Other answers focused on mundane issues such as transportation and course organization (F: "don't have safety concerns, but the situation is confusing with organization, the classes..."). Nevertheless, even with restrictions, students still need and wish to go to campus (K: "I think we don't have to be living in fear."). When asked about COVID-19-related "challenges", some students highlighted routine issues that were present before the pandemic (C: "Parking is costly.") while others said they had no challenges. Students highlighted safety challenges navigating the campus premises. Issues ranged from commuting, social distancing, transportation, and parking (using private cars because of safety concerns); one mentioned room occupancy. Students generally did not mention COVID-19 as a challenge but as a concern, pointing towards the practical nature of the restrictions. Most students mentioned that the safety measures in place were sufficient for them to feel safe enough to come to campus (J: "I don't mind the possibility of catching COVID. I'd rather have that possibility but still come."; L: "Safe, because there is much alcohol [dispensers] everywhere."). One of the main goals of the app was to empower students to decide by themselves when to visit campus daily and feel safe on their necessary campus visits (such as mandatory presential laboratory classes and exams). Most students reported that the app would improve their sense of safety (Fig. 1.2). The safety situation related to the COVID-19 pandemic in Europe improved during the summer and part of Autumn of 2021 and continued to be stable when we conducted the interviews. However, at the point of writing this paper, although the Western world is increasingly vaccinated, the highly interconnected world we live in is still at high risk of pandemics, and safety is still an essential concern.

5.4 Well-being and gamification

Gamification is a useful and successful design strategy that has been successfully employed in many crowdsourcing applications to motivate users. In the context of Tecnico GO!, the purpose of the gamification strategy is primarily to engage users in crowdsourcing information to refine the application sensing mechanisms, contributing through an estimated number based on the number of people they can observe in any given sensed area. This type of crowdsourcing often sees points and leaderboards employed, combined with badges and achievements, levels, and rewards [46]. Nonetheless, feelings about gamification are contrasting. For example, G. reported "I really like It, even the gamification that you have, like the leaderboard, it's interesting". Another one, C., instead, pointed out "This would not really incentivize me because I don't see like an interest in doing this". This finding is not surprising since a similar outcome emerged also in the preliminary evaluation. Moreover, this contradictory feeling about gamification emerges also analyzing the literature since some researchers state its positive effect on motivation and in increasing the users' overall enjoyment of an experience. At the same time, other researchers stress its negative effect. In fact, gamification can be additive, seen as a nuisance, and encourage undesirable behaviors from users.

Reflecting on these findings, the Tecnico GO! project should seek to do more than motivate users to contribute. Therefore, a manifold approach to encouraging participation by incorporating persuasive design strategies is desirable. Persuasive technologies are "interactive systems designed to change people's attitudes and behaviors" [20]. According to the Fogg Behavioural Model (FBM) of persuasive technology, three key components are required to influence the behavior of people: motivation to perform a task, ability to perform a task, and timely triggers [21]. The FBM incorporates a holistic view of the mammoth task of changing

people's behaviors, either to do something to benefit themselves or the party mobilizing the persuasive design techniques. This, in combination with gamification, should change the users' behaviors and motivate them to participate.

6 Conclusion

This paper points to the importance of the Human-Centred Design approach in developing technological solutions for students well being. Despite the fact that the COVID-19 pandemic is currently receding, University students are a population under transition, from teenagers to adults, and because of that vulnerable and prone to mental health risks, stress, and anxieties for the future. Community aspects and solidarity in this transitional period are important for their well-being. We illustrate this premise through the presentation and evaluation of an app developed through this approach and responding to the needs of well-being and community building of the university students population. The results show that students tend to recognize the app's value in learning processes, community building, and the sense of safety, particularly surrounding the features of intent booking and room feedback. Students questioned the rationale of anonymized feedback and less information exposure and voiced their socializing needs. Also, the deployed gamification strategy is well worth further research since it lacks adoption and attraction.

This study proved itself timely in supporting our intent to benefit the student community's well-being, fight isolation, and promote safety in educational settings. Nonetheless, the reported findings have to be seen in light of some limitations. First, the number of users engaged in both evaluations is very limited, i.e., 8 in the preliminary evaluation and 12 in the final evaluation. Second, an additional evaluation should be performed, on the field, asking students to voluntarily use the app for a defined period of time in order to collect actual data (i.e., obtained interacting and enjoying the app). Increasing the number of participants and collecting information about how and how long they would use the app can improve the strength of the obtained findings. Finally, we exploited some basic gamification approaches as external motivation tools, but we didn't exploit and compare different strategies. To make our approach replicate in other contexts, several gamification mechanisms and designs should be evaluated to best address the needs of the interested community.

We foresee keeping improving the app to benefit our student community and university students at large. Considering the rooms occupancy, machine learning can be exploited to predict future values, considering historical, actual, and intent booking data. Advanced gamification strategies can be exploited to engage students in crowdsensing data, creating campaigns, and exploiting external rewards. Additionally, we are considering adding a new functionality suggested by the students: students express an interest in using the app to meet with colleagues and create thematic study groups, keeping safety in mind.

Author Contributions The first author wrote the manuscript, with support from the second author. The third and fourth authors carried out the experiment. The second, third and fourth authors analyzed the data. The first and last authors conceived the original idea and supervised the project, together with the fifth and sixth author.

Availability of data and materials In accordance with the provided consent, the collected data can be used only for research purpose by the authors, and not made available to third-parties.

Code Availability The app is still in the beta prototype and, at current stage, code is not public available.

Declarations

Conflicts of interest The authors have no competing interests to declare that are relevant to the content of this article.

Ethics approval In accordance with the University Ethical Board, ethics approval was not required for this study due to the nature of the collected data and the involvement of users.

Consent to participate The authors collected the participants' consents, following the European GDPR.

Consent for publication Not applicable.

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