Student experience and new media to leverage an Infocommunicational case study model

Maria José Fonseca[1] and Óscar Mealha[2]

[1] School Cluster D. Maria II de Famalicão, 4760-067 Gavião, Vila Nova de Famalicão, Portugal
[2] Dep. Communication and Art / DigiMedia, University of Aveiro, 3810-193 Aveiro, Portugal
mariajosegfp@gmail.com , oem@ua.pt

Abstract. The use of a student's own mobile digital device for learning purposes has been driven by extremely different perspectives. On one side some educational actors advocating the integration and strategically well-planned use of such technologies. On the other end of this spectrum some actors just completely continue to deny the use of such technologies, with students obliged to leave their mobile technologies switched off and kept away in a specific place controlled by the teacher in the classroom. This paper reports an empirical study that used student's smartphone experience narratives, in their daily lives, to design and validate an infocommunicational services model for a learning ecosystem. This work was developed in a school cluster at the north of Portugal in a case study research setup with 141 students, 49 teachers and 46 parents. A smartphone application prototype was designed as a research instrument to simulate the model's characteristics and used to inquire the participants and validate the proposed model. The 8 different prototype task scenarios are explained and the final list of infocommunicational services that comprise the model proposed, designed and tested within this educational community, are a main outcome of this paper. The characteristics of the model are directly related to the case study community's wishes and needs and due to this with generalizable constraints. On the other hand, the research process reveals potential to be adapted and applied to any other educational community, ecosystem, or school cluster.

Keywords: people-centered design, information, communication, user experience, smart learning ecosystems, digital media, school library

1 Introduction

Our time is characterized by recent historical developments that have brought about significant changes in the use of technology. These changes have far-reaching implications and are marked by complexity and unpredictability, particularly since the late 1980s. Presently, the utilization of novel digital technologies for the purpose of generating, retaining, modifying, and disseminating data has undergone a transformation, thereby impacting the economy and society across multiple tiers and magnitudes. A new format has been introduced for knowledge economies, following a

previous format designed for industrial economies, which promotes lifelong learning, creativity, and innovation.

The emergence of diverse temporal and structuring contexts presents novel challenges and prospects the need for introspection and appropriate action, as anticipated by [1].

The diverse range of technological tools and modes of access have allowed individuals to engage with information and communication in novel ways. The use of technology has presented additional obstacles and increased the need for accountability, particularly with regards to protecting privacy, ensuring individual and collective security, and upholding copyright laws. Therefore, it is imperative to understand what is effectively essential, as emphasized by [2] to facilitate the fulfillment of personal needs, growth, and overall life improvement. It is crucial that individuals possess the required knowledge, skills, and attitudes necessary to thrive in the ever-evolving domains of "information" and "media" throughout their lifespan.

With the exponential increase of information and the progress of ubiquitous and ephemeral technology, it is apparent that, more than having technological competences, it is necessary to have digital awareness, and to know when, and how to use information. In this setting, the educational environment, and particularly the librarian teacher, has the task of educating for media with media, building on the necessary literacies and digital competences to access, and read in a critical, creative, and constructive manner to meet the student's purposes.

According to [3], the integration procedure is comparable to "sewing". The key to generating something of value can be pursued by assembling all the components and ensuring that they are compatible with one another. Not only in terms of the physical body, but also the intrinsic rationale of each individual. To determine the pertinence of the components and the most efficient way to connect them, one must be capable of critical thought. To effectively complete the task, one must be able to "think autonomously and act with one's hands." There is an increasing need to readapt to a new culture that is traversed by hybrid formats, multimedia, and hypermedia in times that are significantly influenced by economic, social, and cultural transformations, as well as advances in the scientific and technology fields. Borders and identities are also being reshaped, which calls into question the "I" in the world of technology. This has fostered change in the way of being, interacting with others, and behaving in response to a new globalized and globalizing environment. We are witnessing new methods of adaptation to the digital environment, in the search for solutions that enhance other paths in the teaching and learning process. Future learning ecosystem technologies should be more narrative-driven, flexible, and customized to match the needs of individual students [4]. This is the only way that current active learning methods can make sense within a student-centered educational paradigm. An effective educational program must have a student-centered approach, adequate learning methodologies, resources, infrastructures and technology-mediated services that incorporate students' experience narratives.

By analyzing and evaluating the potential of a common mobile technology in a school setting, can help to dispel the notion of prohibiting and instead encourage its use, adopting a critical, conscientious, and constructive stance towards the equipment that is nowadays in everyone's individual possession. Although smartphones are ubiquitous and provide access to the internet and numerous applications, formal

education systems have many uncertainties concerning their pertinence. This view, which may reveal discomfort in its use, is beginning to be challenged by the fact that mobile learning is associated with new competences and assumes a significant role in education and for the future. This perspective of educational systems in relation to "popular digital technologies" is founded on the increasing "irrelevance" of education to today's students, [5]. This perspective is based on a modernist structure, where students integrate "education factories" that prepare them for a world that no longer exists, as opposed to developing cognitive skills that will create individuals prepared for contemporary citizenship. Currently, the younger generations and those following have undoubtedly adopted a way of life that is facilitated by digital technology. A considerable portion of their daily tasks are mediated by digital services that are conveniently accessed through their personal computers, smartphones, or tablets. Academic institutions, including some schools, have incorporated technological platforms within their educational ecosystems. Some examples of these platforms are Google Classroom, Google Meet, Google Drive, Padlet, Socrative, YouTube, Kahoot, and Plickers, just to mention some. The design process adopted for these platforms frequently prioritizes the enhancement of services, functions, and attributes from the viewpoint of professionals and specialists, while neglecting the user's narrative or the perspective of the student or learner. Scientific literature strongly suggests that the technologies employed in upcoming learning ecosystems should be tailored to incorporate the narrative of the student's experience. The reason for this approach is to assure better alignment with the expectations of the student and to facilitate an optimal learning experience [4]. The effectiveness of modern active learning techniques is contingent upon the adoption of a pedagogical approach that prioritizes the needs and interests of the learner. Ensuring proper alignment and structure of all components is crucial in enabling the effective implementation of a uniform learning strategy and approach.

The identification of the key players to promote and encourage change in a learning environment is another important problem. Are the school library and librarian teacher strategic agents for this endeavor? A new educational paradigm requires an educational model for autonomy, critical thinking, and lifelong learning. According to [6], the librarian teacher as an agent of change, with specific competences and knowledge can motivate and influence the different actors of the educational ecosystem, identify needs, consider student uniqueness, and engage with teachers to “co-plan, co-teach, and co-assess a lesson or unit of instruction". Thus, the librarian teacher can "leverage" educational success by training students to use technology and information to promote critical and creative autonomy in all instances driven by ethical principles. Sharing resources particularly in educational ecosystems increases learning chances for all due to democratic, collaborative, and leadership relationships amongst educational actors. The librarian teacher creates a student-friendly, learning-friendly library atmosphere [7]. Librarian teachers oversee curriculum, manage information services, and are information specialists extremely sensitive to stakeholder/human needs.

The librarian teacher's primary roles are teaching, management, leadership, cooperation, and community engagement support to the library's role as a collaborative partner in student learning and training. This new position requires the library to adopt new organizational and management methods to meet the needs of

many educational actors in close collaboration with each other. The library can be anywhere, giving people information at their fingertips at school, home, on the bus, or in the park - if users find what they need, this ubiquity will boost engagement. Technology can optimize “physical and digital access to the library,” and school library information resources can be accessed across the school and beyond [8]. This two-way model allows democratic access to school library resources 24/7.

With the relationship of multiple document formats and information, school libraries become connected-user environments rather than collection spaces. "Powerful elements of change and innovation, capable of providing new ways of learning and interacting," school libraries "extend the time and space of learning from inside to outside the classrooms and inducing new practices and literacies," according to [9].

The work reported in this paper also addresses the process that should be adopted to leverage and manage change and effectively achieve “a better learning for a better world”, a major concern announced in SLERD 2022, as a contribution to [11] Agenda for Sustainable Development Goals (SDGs). A participatory research process developed in the scope of a community was adopted and capable of engaging all educational community stakeholders. Students, teachers, and parents were participants of a qualitative inquiry, inductive research project contextualized as a case study at the head school of school cluster D. Maria II of Vila Nova de Famalicão, Portugal. The student’s perspective and experience narratives were the driving force to co-design an infocommunicational model mediated by smartphones, in fact capable of aligning with a Bring Your Own Device (BYOD) strategy [12].

2 Related Work

Within relevant technological immersion, young people acquire, from an early age, several competences, and interests for which traditional education is not prepared. The very concept of "need for information" deserves special attention in the case of younger individuals. As mentioned by [13], "We often forget to sit next to teenagers and ask how they are seeing the world. If we did, we could soon realize that everything has changed around them, especially the way we communicate with each other today" [p.30]. In addition [14] says taht "Most teens are online to interact with people in their community" because in this space of interaction or "escape" is where they find "Cool locations" and look for a "space of their own" to understand the world beyond where they are. It is therefore considered fundamental to understand their online interaction narratives - how they do this, what meanings are obtained and for what purpose do they do this. This complicity between human beings and mobile devices can take on an elusive dimension as [14] recalls: “The Internet provided me with a wider world, a world populated by people who shared my idiosyncratic interests and were willing to discuss them at any time, both day and night. I grew up at a time when being online – or connecting – was an escape mechanism and I wanted to escape desperately” (p. 20). The smartphone has become an inseparable device for everyone, and the teacher cannot ignore it. It’s necessary to recognize the pertinence of the students' smartphones taking advantage of the Bring Your Own Device

(BYOD) strategy [15]. As demonstrated by [12], it is essential for educational ecosystems to explore alternative and innovative formats that integrate BYOD strategies with adequate methodologies. This possibility for students to bring their personal devices to school can potentially lead to a restructuring of educational methods, prioritizing networked learning and fostering connections between students and teachers. This can create a community of shared resources, interests, and knowledge acquisition. The access to online teaching resources on students' devices complements the teacher's and manual's knowledge, introducing new educational practices. The system's focus on the student and learning activities motivates and engages [16]. Given the results presented in [15], students reported benefits associated with the BYOD model, namely that the use of personal devices for classroom activities contributed to a more conducive and favorable learning environment.

The Transliteracy H2020 Research and Innovation Actions[1] exhibit a distinct emphasis on the appreciation of novel methodologies, particularly with regards to the employment of digital media and tools by the younger generation for educational purposes and other activities. The establishment of an affective atmosphere and collaborative design process is crucial for educators to effectively connect with their students. The practice of listening and demonstrating empathy, which goes beyond traditional media-centric teaching methods, is expected to yield substantial benefits for students. This approach is anticipated to establish a strong connection between students' interests and the academic objectives of the institution [17]. The use of mobile devices, specifically smartphones, is deemed necessary in the educational process as evidenced by the MILAGE app Aprender+[2] and the SMARTEEs Project: Smartphones in Educational Ecosystems [18], [19].

Simultaneously, the opposition towards technology persists, whereby any item within the classroom can be deemed as a technological device, dating back to the era of the blackboard (chalk), notepad, and even printed literature. Merely providing schools with computers is insufficient if they are not conveniently used or maintained with regular updates. The presence of apprehensions or inadequate instruction often presents challenges; however, it is essential to facilitate media literacy to navigate educational, social, cultural, and political environments. The presence of modernity in a school that adheres to several parameters from the eighteenth century creates a mismatch that requires a redesign of the educational and political interfaces, as suggested by [20]. To facilitate this redesign, it is crucial to actively engage with various stakeholders, carefully analyze their objectives, and prioritize key elements within a comprehensive modernization framework. Additionally, it is important to establish clear goals for change and implement an iterative process, as exemplified by the SMARTEEs model. The process in question should involve the active

[1] https://transmedialiteracy.org/
[2] https://apps.apple.com/pt/app/milage-learn/id1140 872254
[2] https://apps.apple.com/pt/app/milage-learn/id1140 872254

participation of students, teachers, and families to collaboratively design and capitalize on the potential of using smartphones both inside and outside of the classroom. This approach can facilitate the creation of novel phygital (physical + digital) learning environments that promote reflective and meaningful learning experiences.

In addition to the perspectives presented regarding the use of personal mobile devices, it is important to reflect on a new approach to information accessibility in the field of education: the ChatGPT. Artificial Intelligence (AI) delivers several products capable of promoting many significant challenges in education and introducing innovations in teaching and learning methodologies. At the same time, the use of these new and disruptive AI technologies should guarantee and be guided by the principles of inclusivity and equity [21].

The ChatGPT, supported by a large language model, (LLM) has been created by OpenAI, which is a research laboratory consortium specialized in artificial intelligence. The architecture utilized in this system is founded on the Generative Pre-trained Transformer (GPT), which was initially presented in 2018 by Alec Radford, Karthik Narasimhan, Tim Salimans, and Ilya Sutskever, who are researchers affiliated with OpenAI. The initial GPT model underwent training on an extensive corpus of textual data sourced from the internet, employing the method of unsupervised learning [22]. The model enabled us to acquire the ability to produce logically connected written discourse in diverse genres and structures, encompassing expository writing, narrative prose, and verse. OpenAI [23] unveiled a novel iteration of the GPT model, dubbed GPT-3, in June of 2020. This updated version boasted a substantially greater number of parameters than its antecedent and was trained on a dataset of even greater magnitude. The GPT-3 model has garnered significant interest due to its proficiency in executing a diverse range of natural language processing tasks, including but not limited to language translation, question resolution, and essay composition. ChatGPT is a specialized iteration of the GPT-3 algorithm, which has undergone tailored training to excel in conversational applications, including but not limited to, responding to inquiries, and engaging in interactive exchanges with users. In 2020, OpenAI unveiled the GPT-3 API, which provides developers with a straightforward web interface to leverage the model's functionalities.

In general, the emergence of ChatGPT and similar language models represents a noteworthy achievement in the domain of natural language interfaces and processing. This type of product transforms our mode of interaction with both machines and individuals, capable of increasing the effectiveness of our cognitive skills and outcomes. Since ChatGPT is a Deep Learning-based natural language learning tool, derived from numerous examples of human dialogues, it can be a resource for education. This model is deemed to be a supplementary instrument for research and verification of information. ChatGPT has undergone extensive language modeling training on a vast corpus of textual data, thereby enabling it to generate responses to a diverse array of inquiries and provide knowledge pertaining to a multitude of subject matters. Just to mention some examples of ChatGPT outputs: i) it has the capability to facilitate ideation and retrieve pertinent data on a specified subject matter through the

process of conducting searches; ii) can respond to user inquiries by leveraging its pre-existing knowledge base. It is crucial to bear in mind that ChatGPT's reliability cannot be disregarded, and the precision of its responses may be highly dependent on the data used to train the model. To ascertain the veracity of the data furnished by ChatGPT, it is imperative to corroborate the information with alternative sources and undertake additional research, if deemed necessary. In general, ChatGPT has the potential to serve as a valuable instrument for conducting research and verifying data, however, it is recommended that it be utilized in conjunction with additional sources and with the application of critical analysis. This process of information retrieval, management and curation should always be accompanied by teachers and subjected to critical evaluation [23]. It is therefore crucial to evaluate factors such as the credibility of the source, the relevance of the information, and potential biases. However, it is an auxiliary resource for research and peer review, allowing for efficient validation and investigation of information. Although it is a unique tool, it should not be exclusively used as a primary basis of information [24].

It can be inferred that these AI products in the field of education allow rapid and timely access to information in a significant way to monitor and assist both teachers and students at different stages of the educational path. Several use cases of this technology include developing interactive teaching materials, facilitating problem-solving tasks, and providing personalized feedback.

However, it is important to recognize that it is not a panacea and should be used by students with caution and always with the support of teachers or even family members with adequate literacies and competences. Furthermore, it is crucial to consider potential ethical and privacy concerns while ensuring that all students have an equal opportunity to use the technology.

In short, the use of technology supported by AI models can prove to be an asset in contemporary education, provided it is employed appropriately and equitably.

3 Method

Vila Nova de Famalicão is a Portuguese city in the Ave sub-region, belonging to the Northern region of the Braga district, with 20 935 inhabitants in its urban perimeter. It is the seat of the municipality of Vila Nova de Famalicão, with a total area of 201.59 km^2 and 133 574 inhabitants, subdivided into 34 parishes. The participants in this study were selected from the 2^{nd} and 3^{rd} study cycles, namely the 5^{th}, 7^{th} and 9^{th} years (ages from 11 – 15), to better understand their infocommunication procedures in new media, used daily between home and school and in the classroom. The interaction narratives that result from smartphone use procedures, present in these students' daily lives, will inform a teaching and learning tool in the classroom context and/or in another learning context. The experience and opinions of 5^{th} year students are particularly pertinent because this part of the sample's population is starting a completely different education cycle, in which many of them have a smartphone for the first time.

The Case Study [25], [26] research reported in this paper was coordinated by the principal researcher, a librarian teacher that was also a contextual observer of the

relevant situations in and outside the library. A Design-Based Research (DBR) [27] process was chosen, originally proposed by [28] and promoted later by [29] as a method capable of contributing to "design Science". DBR integrates co-design processes to validate with stakeholders an infocommunicational model mediated by smartphones to be used for learning purposes. The infocommunicational model was, from a very early stage, represented and discussed as a conceptual digital prototype and used as a research instrument during the different inquiry phases to validate and improve the model. The prototype's initial version was developed in the 1st DBR iterative cycle and a second version in the DBR 2nd iterative cycle. In both instances guided by Design Thinking [30] and a Double Diamond [31] participatory design process, nurtured by divergence and convergence reflection [32] in both DBR instances (Fig. 1).

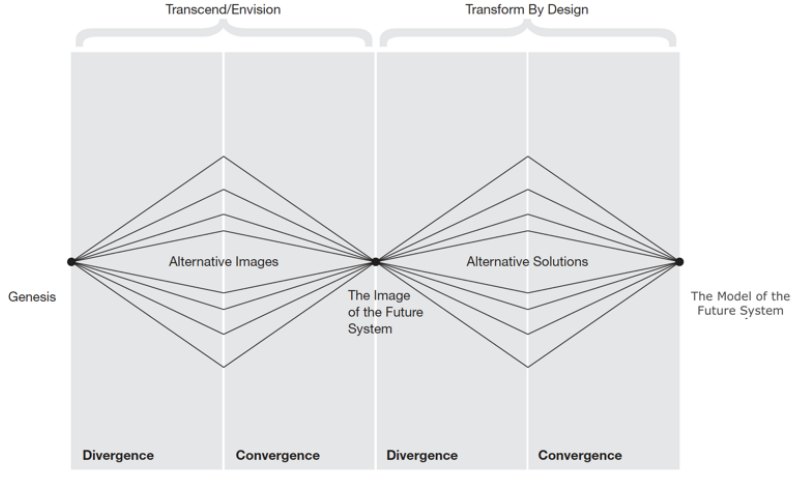

Fig. 1 Divergence and Convergence thinking in a double diamond representation. Source [27, p.24].

3.1 Procedure

The empirical study was contextualized by a case study and gathered empirical data (with 236 participants) in different moments of the research timeline, Fig. 2, integrating different research instruments complemented by a DBR process: (i) a systematic literature review (SLR) that informs the main concepts, methods, and related work reported in this paper; (ii) the benchmarking process that compared similar platforms and applications that are being used in the classroom and other social/collaborative platforms, used by students capable of also being configured to be used in the classroom; (iii) questionnaires, mediated by the research team and applied to students (n=75), teachers (n=20), and parents (n=20), to collect a corpus of student experience narratives and opinions; (iv) direct observation; and (v) iterative (DBR) design of a conceptual prototype used to test participant's experience and rate their

opinion on a set of scenarios and user narratives co-designed with data collected from student's experience narratives and opinions.

The prototype was designed in 2 DBR iterations. In the first iteration the prototype's 5 task scenarios were pre-tested with 6 students out of the 1st cohort. These insights influenced the re-design of the prototype into 8 task scenarios. The final version of the prototype, discussed in this paper, was then tested with students (n=60) and validated with teachers (n=29) and parents (n=26). This last DBR validation phase was performed by some participants that also belonged to the 1st cohort but due to the time lapse between moments, they belonged to a different study grade. The content analysis was carried out systematically, on the narratives of the different actors involved, to quantify and cluster the occurrence of phrases or "key" words / concepts for comparison and verification. The clustering of the units of analysis into conceptual categories reduced the amount of data and facilitated the interpretation of the interaction between them and extracting the essentials. The treatment and aggregation of the quantitative and qualitative data from the surveys made it possible to organize the answers of 5th, 7th and 9th grade students, as well as teachers and parents, which proved to be most relevant to the set of questions of the dimensions of the theoretical-methodological framework: media literacy, smartphones and school library.

The first questionnaire, applied with open (OQ) and closed questions (CQ), was organized into three main dimensions, as detailed in Table 1 - media literacy, smartphones, and school library.

Table 1. Relationship of the Survey Questions to the Dimensions under Study: Media Literacy, Smartphones and School Library, CQ, and related OQ, by [33, p.19].

1. Media literacy
CQ1. Do you have a mobile phone with smartphone features?
CQ2. How long have you been using it?
CQ3. Would you like to have a smartphone and what for?
CQ4. How many hours do you use your smartphone per day?
CQ5. How many days do you use your smartphone per week?
OQ5. For what purpose and which applications do you usually use your smartphone?
CQ6. Do you usually use your smartphone at school? RF: Yes or No
CQ7. Where in school do you use it? RF: Yes RF: Multiple-choice answers:(1) Classroom; (2) Library; (3) Refectory; (4) Playground.
OQ7. ANS: No 7. What is the reason?
OQ7. ANS:: Yes 7. What use do you make of your smartphone in these places?
2. Smartphones
2.1 Classroom
CQ8. Can the smartphone be a working tool, for teaching and learning, in a classroom context?
CQ9. What activities could be added in the classroom by using the mobile phone (smartphone) to enhance teaching and your learning? RF: Multiple choice answers: (1) Content sharing (teacher-student); (2) Clarification of doubts (student-teacher and between students); (3) Study organization; (4) Self-study; (5) Information search; (6) Group work; (7) Presentation of work;

(8) Evaluation (teacher-student and between students); (9) Information (teacher-student and between students); (10) Decision-making (class voting process); (11) Curriculum challenges; (12) No activity.
OQ9. Given your answers to the previous question, in what ways would you use the smartphone to carry out the activities? And to solve what?
OQ9. In which subjects could the smartphone be used, inside or outside the classroom? Please indicate why?
CQ10. Do you agree that there should be rules on the use of smartphones at school?
OQ10. In view of your score, would you please comment on and state the rules of your school regarding the use of the smartphone?
2.2 Outside the classroom
CQ11. What about outside the classroom? Can the smartphone still be a working tool?
CQ12. Outside the classroom what activities would you use on the smartphone to enhance teaching and your learning? RF: Multiple choice answers: (1) Distance learning (class constitution, presentation and discussion of work); (2) Content sharing (teacher-student, teacher-tutor); (3) Clarification of doubts (student-teacher, between students, teacher-tutor); (4) Organization of study; (5) Monitoring school progress; (6) Self-study; (7) Researching information; (8) Group work; (9) Evaluation (teacher-student and between students); (10) Information (teacher-student and between students); (11) Decision-making (class voting process); (12) Curriculum challenges. No activity.
OQ12. Given your answers to the previous question, do you use your smartphone differently outside the classroom? Why do you do this?
OQ12.What have you enjoyed most related to using the smartphone at school?
OQ12. What are the biggest problems with using the smartphone at your school?
OQ12. What about at home? Do you have problems using the smartphone that you would like to share with us?
3. School Library
CQ13. The school library is a physical and digital (virtual) space for co-producing and sharing content.
OQ13. Given your score, how might the school library improve its services to enhance your learning?
CQ14. Would the existence of a dedicated app make it easier to access the information and services that the school library provides?
CQ15. Given your answer to the previous question, please tick below all the key features that this app should have? RF: Multiple choice answers: (1) Distance learning area (e.g. Google Meet, Microsoft Teams, Zoom, etc); (2) Dissemination/reaction area (e.g. Classroom, Edmodo, Facebook Groups, Youtube, Reddit, etc); (3) Personal/collaborative work area (e.g. Google Drive, Jamboard, Dropbox, Microsoft Office Online, Google Meet, Microsoft Teams, Mic, Zoom, etc); (4) Organization/study planning/tasks/events area (e.g.: Google Classroom, Google Calendar, Edmodo, Padlet, Socrative, Google Keep, Microsoft Outlook, Notion, Asana, Trello, etc); (5) Communication area (e.g. Messenger, WhatsApp, Slack, Microsoft Teams, Zoom, Skype, etc.); (6) Assessment (teacher-student and between students) (e.g: Google Classroom, Kahoot, Google Forms, Edmodo, Padlet, Socrative, Poll Everywhere, etc); (7) School performance/progress visualization (e.g. Edmodo, Padlet, etc); (8) Information/document sharing (e.g: Google Classroom, Google Drive, Microsoft Teams, Zoom, Skype, Email, Dropbox, WeTransfer, etc); (9) Content search (Google, Reddit, Youtube, Wikipedia, etc); (10) Decision making (in a voting/comment process) (e.g. Kahoot, Poll Everywhere, Socrative, etc);

(11) Posting curriculum challenges (e.g. Kahoot, Facebook, Instagram, WhatsApp, Reddit, etc); (12) No opinion.
OQ15. Why don't you agree with an app with these features?
OQ16. In this conversation do you think we have missed any issues related to the use of smartphones in your school or at home?

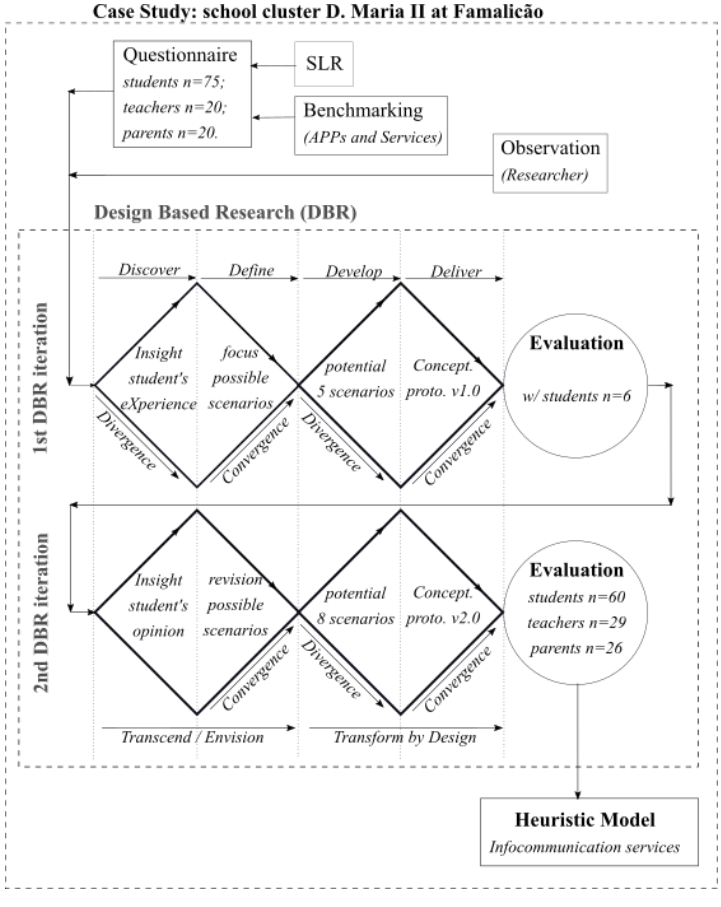

Fig. 2 Symbolic representation of the Case Study integrating a Design-Based Research process, adapted from [33, p.18]; [34, p.24].

The organization of the questionnaires, with similar questions, was processed into three questionnaires directed to the three different target groups of participants: students (5th, 7th, and 9th grades), teachers (2nd and 3rd study cycles), and parents. It was structured with closed questions to score opinions on a linear numerical scale between 0 (minimum) and 9 (maximum), as well as open questions, to collect the opinions and/or comments regarding the score in the closed questions. These questionnaires were applied to a sample of 115 participants, 75 students (5th grade,

n=33; 7th grade, n=25; 9th grade, n=17); 20 teachers; and 20 parents. The research process took place at the head school of D. Maria II school cluster at Famalicão, Portugal, from October 2019 to October 2021. Most of the empirical work took place during COVID-19 and more than 80% of the data collection process was done online via Zoom audiovisual platform. The research process had the formal approval of the Management Board of the school cluster and of the Portuguese Ministry of Education with code n.º 0576100002 that included the approval of research instruments, research process, and all ethical consent forms and procedures.

The identification of the most pertinent new media usage procedures, among the announced profiles, in the context of using smartphones for learning purposes in various contexts (such as the school, the classroom, and environments outside the classroom) stems from the information obtained. The conceptual prototype is nurtured by the infocommunicational procedures identified and validated by the study subjects.

With the aim of linking results to expected functions, in a design informed by the infocommunicational procedures reported by participating students, and through investigative iterations, the conceptual representation of version 1.0 of the model was presented to the students.

In late November 2020, the first tests of the first iteration of the new media conceptual prototype, designed to incorporate infocommunicational narratives, were conducted. These tests involved the use of intermediate resolution mockups. The evaluations allowed for the validation of the infocommunicational procedural narratives of six 5th and 7th grade students in the previous school year, when the questionnaire surveys were applied. Due to the pandemic, the sessions were conducted through the Zoom platform, using videoconferencing technology. The present provisional version, which was revised and co-constructed (with students not only serving as subjects of observation), operated as a research tool that was refined collaboratively throughout the study.

4 Student Experience Narratives and the Prototype

After identifying how students use their smartphones, (at school, classroom, and outside the classroom), Figs. 3 and 4, results reveal that only 9.33% (7/75) do not own a smartphone. Regarding this and asked whether those who did not have a smartphone would like to have one, the five participants of the 5th grade answered yes *to play, communicate, and socialize and to be able to play with my friends, to talk to them from places where they are not, and to talk to my parents*. As for 7th grade participants, the two students said they did not have a smartphone, but they would like to have one *to communicate better with everyone in the classroom and do activities*. Associated with the previous elements, the students were asked about the purpose for which they used the smartphone—there are activities common to three grades (5th, 7th, and 9th grades), namely playing games; communicating; watching videos; sending assignments; researching; taking photographs; social networks.

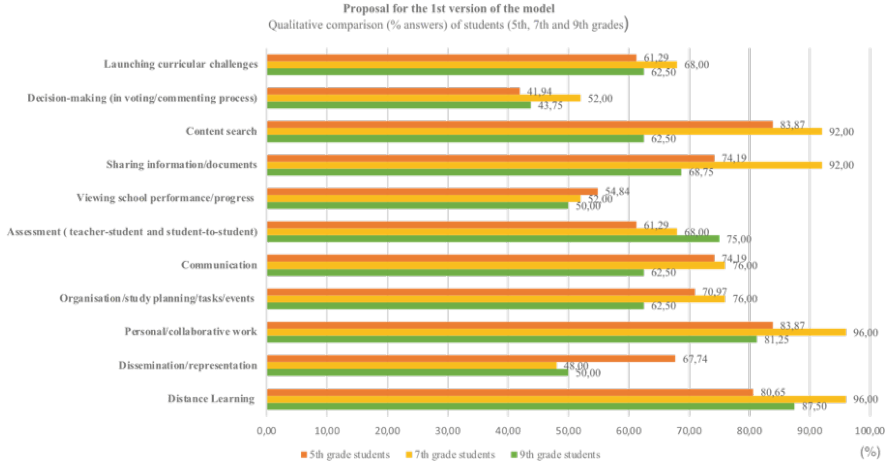

Fig. 3 Student score mentioning how they use their smartphones collected in the first questionnaire.

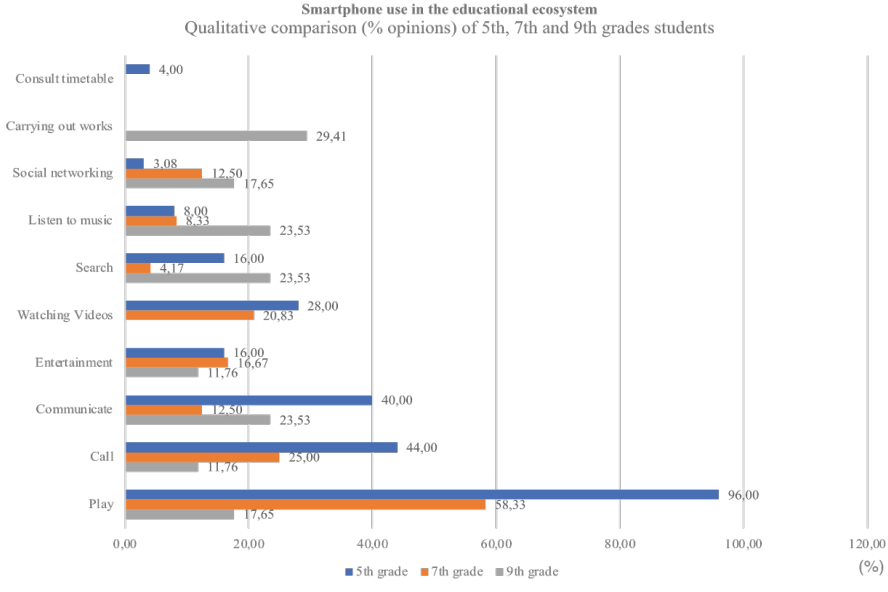

Fig. 4 Student experience narratives collected in the first questionnaire applied and mediated by the research team.

The data collected from this initial inquiry process was processed by the research team and designed into eight scenarios and corresponding user narratives as systematized in Table 2.

Table 2 Scenarios used to iteratively design the conceptual prototype in a DBR process.

Scenarios	Goals
1	Simulate the registration experience, visualize the tutorial, and explore the information available in the student's personal profile
2	Explore the information available about the subjects (general objectives, timetable, and teacher profile)
3	Consult student's former grades and school calendar
4	Initiate a private conversation with teachers to ask questions, from the teacher's profile or from the conversations tab
5	Create a conversation group from the option in the main menu
6	Access an activity, create a document, and view the information provided by teachers from the library
7	Explore notifications and understand the process of submitting activities and assessments
8	Identify the functionalities of the library and consult the books available

The following relation of smartphone screen images, depicted in Fig. 5, represents two of the student's experience narratives, Profile/Subjects and Former Grades, used in a 1st version of the conceptual prototype, two left screens, and then re-designed in an iterative DBR participatory process to achieve the two screens on the right.

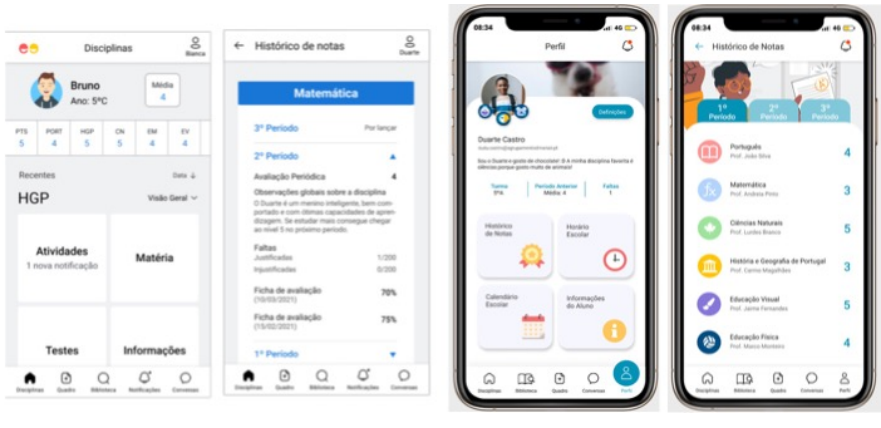

Fig. 5 Student experience narratives of Profile/Subjects' and Former Grades—two left screens 1st version and two screens on the right—2nd version of the conceptual prototype.

This participatory process of iterative DBR, which results from the students' narratives, allowed reaching a 2nd version with graphical corrections and new interfaces, to improve the context scenarios, as well as explore other existing functionalities and measuring their effectiveness. In addition to being improved in design and composition, this 2nd version has also been improved about the hierarchy of information; textual intensity; chromatic use and iconography facilitating navigation and perception of the structure of this tangible interface deeply representative of the infocommunication model (Fig. 12) Considering the issue of Accessibility, it has an audio-description tool, for students with difficulties at level of attention, hearing and reading. This option can be enabled for the entire application. Within the Settings page it´s possible edit the student's registration information, namely selecting *interest badges*, as well as (right side of Fig. 6), turn on or off app notifications.

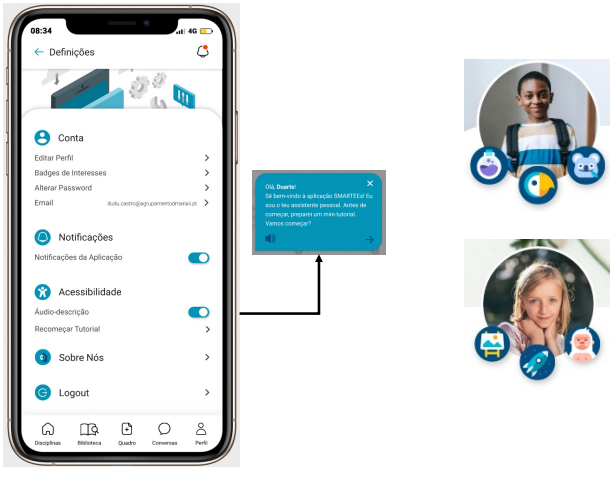

Fig. 6 Holds two Figures: Definition Layout (left side) and Badges of Interest (right side).

In the sense of greater interaction between peers, as well as more participation in different activities, promoted by the educational ecosystem or external entities, the public component of the student was refined according to the suggestions reported by the students. The implementation of interest badges is associated with the personalization of the information and the motivation that can result from the study, allowing the student to select 3 badges to add to the profile. Also, student participation in extracurricular activities (reading contests, spelling, school sports, math Olympiads, clubs, or others) is visible. As for the private component, the student will consult the school calendar, the schedule, information about the person in charge of education and their grade history (Fig. 7).

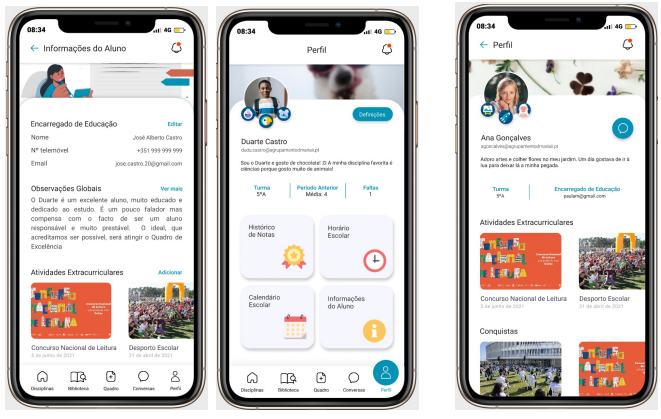

Fig. 7 Private and Public Component of the Student.

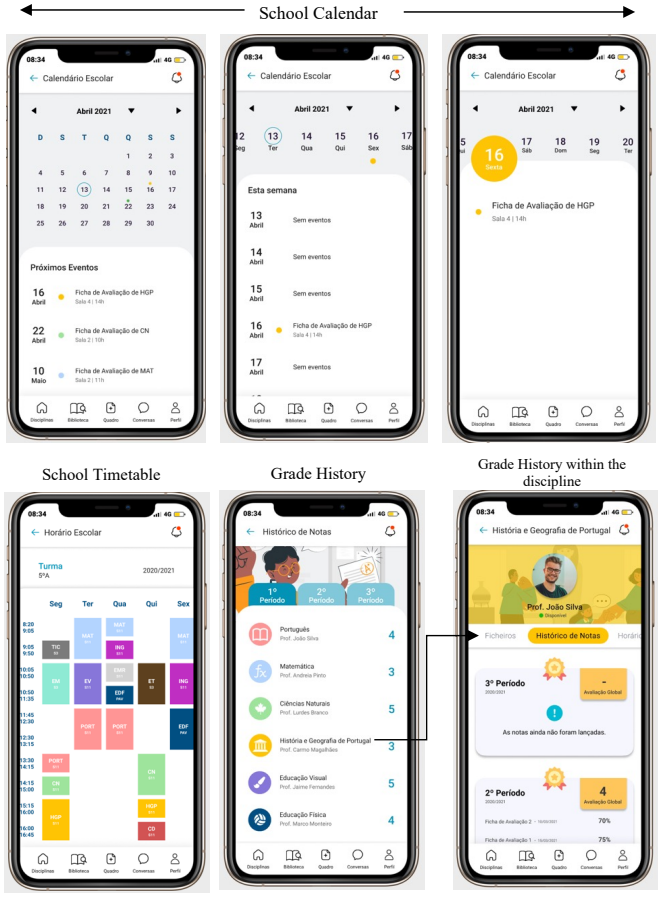

Fig. 8 Changes to School Calendar, Time, and Grade History.

As shown in Fig. 8, there were improvements to *the school* Calendar, *in the* Time and in Grade *History*. As for *the School* Calendar, it appears more intuitive and complete, being possible to access the day, week or month, *the Schedule* was created according to the one made available at the beginning of the school year, by the educational ecosystem, but with the subjects indicated with a certain color, for a more intuitive and fast visual association. Regarding the *Grade History*, considering the students' narratives, it was separated by period only with the final grade of each subject where the *student is oriented to the tab* "Grade History" within the Subject with more detailed information about the evaluation, such as observations inserted by the teachers.

As for the Subject´s page, the list of subjects and the name of the teacher, as well as a space for the "next activities" appears. Each subject has an information icon, to access the objectives, presents itself in modal version for non-regular consultation, prioritizing the essential information. The student can also access the activity history in the Activities tab and the schedule of the subject in the Schedule tab. If necessary, the student can contact the teacher directly through the teacher's profile, creating a communication channel with the necessary proximity, within the professional scope, as shown in Fig. 9.

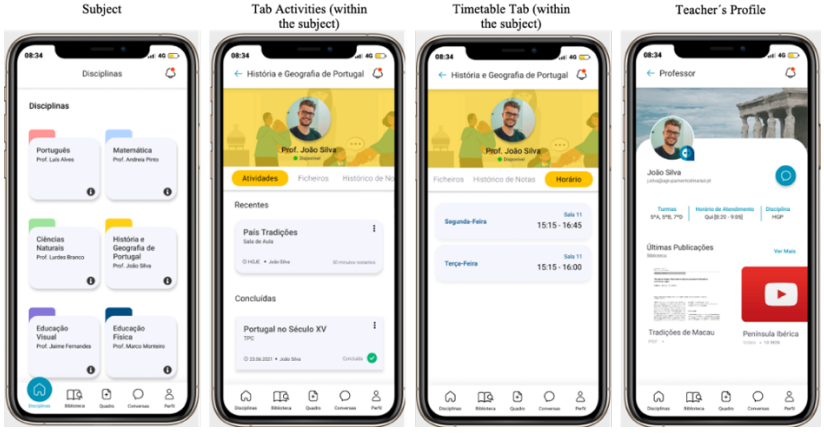

Fig. 9 Subject's Layout, HGP and Teacher´s Profile page.

Peer evaluation remained in the application, considering the narratives of the participants in the evaluation of v1.0 of the model. This procedure takes place in the Discussion area, at the moment the work is sent to the teacher, where students have the possibility to evaluate by stars (from 1 to 5). When evaluating the work of colleagues (Evaluation modal), they will necessarily have to insert a comment that underassessed evaluation given (Fig. 10).

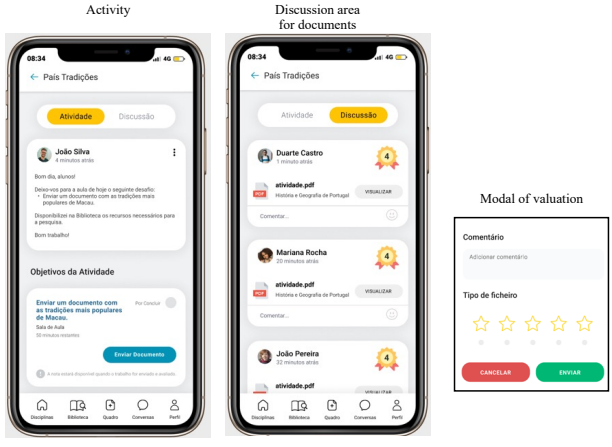

Fig. 10 Profile Page layout of an Activity Posted by a Teacher.

In the Library area, (Fig. 3.1) the user can find the files made available by the teachers, organized by subjects and year, as well as synopses of books from the documentary fund of the school library, with the possibility of ordering and marking as already' read and / or favorites. Although this part appears completer and more appealing, it is considered to have enormous potential to encompass other infocommunication content.

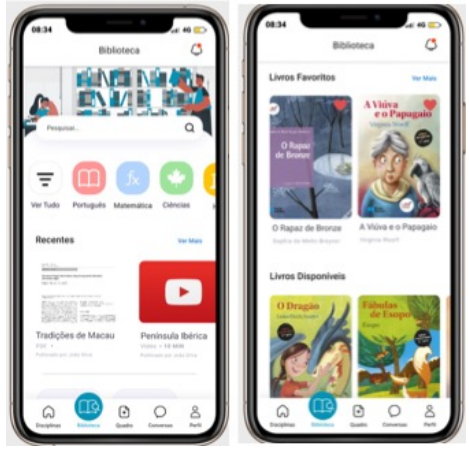

Fig. 11 Library ´s Layout.

5 Elements of the Heuristic Infocommunicational Model

This section describes and discusses the main findings and contributions of this work, the infocommunicational services validated with the DBR process, and the conceptual

prototype[3], in the case study. These services, a contribution of this study, were identified in the specific context of this research and their pertinence is not generalizable to other learning ecosystems. The research process on the other hand proved to be adequate to be applied in other similar learning ecosystems because the method and data collection techniques are not context dependent.

The infocommunicational services that were identified and validated by the different sample's cohorts, collected from students' experience narratives can be described as follows:

- **Access to personal information**—This information was suggested by the students with inspiration in the typical profile element common in a mobile device app or web product. It can be structured with personal private information concerning the parent/tutor, the student's former grade history, class timetable and other school activities and responsibilities. This element should also register the student's participation in extracurricular activities (reading contests, spelling, school sports, mathematics Olympiad, clubs, or others). Some of these extracurricular activities were in fact mentioned to be public (optional) as an instrument to foster socialization with other fellow colleagues or other school actors (teachers, staff, or parents) that might share the same activities or interests.
- **Implementation of "interest badges"** —This is associated with the previous personal information element as a motivational instrument that may influence learning, foster socialization, and consolidate reputation amongst peers. In this version of the model the student can select from a set of three badges to add to the profile, related to a specific profile characteristic and to depict a certain level of performance or mastery. This kind of personal identifier, alongside other human values, and appropriate community behavior, such as mentoring, can empower leadership. Nevertheless, filters may be needed in the sharing of interests and should be supervised by parents. The students consider that knowing the interests of their colleagues, namely the classmates, will mean understanding him/her better, which, in part, may prevent unpleasant situations and alternatively foster empathy. Badges were pragmatically mentioned as graphical representations of a typology of interests to quickly identify common interests among community members such as students or teachers, e.g., fishing, birdwatcher, volley-ball player, science-fiction reader, etc.
- **Interpersonal communication**—This element is related to the proximity of the different educational actors, namely teacher-student, which will favor the learning process, such as the clarification of questions (student–teacher), as well as more confident and motivated communication situations in the classroom. The proximity relationship that arises from this will provide greater sociability between the different players due to the common interests identified, favoring the creation of more empathic relations in the educational ecosystem.
- **Organization of information**— Information structure without an organizational strategy will not foster an intuitive access. Useful and relevant information has to be adjusted to the educational ecosystem needs and organics, with updated content, directed and organized for each school year and subject, with the possibility of

[3] The 2nd conceptual prototype, available at https://bit.ly/3Od96Xy , details all eight scenarios and user narratives built in a DBR iterative participatory approach.

following the activities/tasks in each one of them. Some empirical evidence of this study, led us to affirm that if all relevant student's information were integrated on a single platform, mediated by an individual's device (e.g., smartphone) and customizable for each stakeholder (end user), it would encourage more timely and effective usage of these tools/applications. Doing so we would contribute to a perceived affordance of the application for the purpose of an educational ecosystem.

- **Student performance information**— The "anytime anywhere" paradigm is extremely appropriate to drive the immediate and systematized access to relevant information presenting a generic and detailed on-demand view of the student's performance. This academic performance, for example, regarding each subject, curricular and extracurricular activities, will facilitate a closer and effective monitoring of the student's school career. Each student should develop a sense of autonomous engagement in following up how they are performing in each and any activity of the learning ecosystem. This should potentiate more transparency, individual continuous responsibility, and dedication to learning subjects that are shown with lower grades or assessment or need improvement.
- **Synchronous and asynchronous conversations**— Human interaction and communication performs better when the synchronous and asynchronous communication modalities are promoted in articulation. These kinds of communication services create the possibility to start conversations with colleagues and teachers, as well as to create discussion groups to support collaborative work or just to chat. Work group situations that have a face-to-face strategy can be backed up with this kind of infocommunication and sharing services. Work responsibilities and milestones can be followed up and documents shared without disturbance of other workgroup elements' dynamics. Students' narratives were very clear in mentioning third party instant messaging services that support their needs, such as WhatsApp or other messaging services, some associated to their digital social online networks.
- **Collaborative work**— This element is fundamental in a group learning strategy or paradigm. This model's element highlights the need of collaborative work services, that facilitate and/or mediate group work for the creation and sharing of information, knowledge, and documents in various formats (e.g., text, presentations, excel…). This collaborative work possibility, with colleagues, will allow fine-tuning details and automating procedures so that the student (or any other stakeholder of the work in progress) does not get lost. Consider the insertion of a multimedia whiteboard, for the execution of joint and synchronous activities. This is one of the model's elements that occurs as a natural student narrative reporting what already happens in third party infocommunication services to support classroom group work, such as Google docs and drive.
- **Submitting work for assessment -** Personal devices such as nowadays smartphones are also commonly used to check or validate final work decisions or documents. This model's element should assure that the submission of an assignment, project or report for assessment is done in an intuitive, and effective procedure. The student should be able to develop and submit some of the schoolwork forms or reports "anywhere and anytime", inside or outside the classroom/learning ecosystem. The fact that "all" schoolwork could be on the same platform, highlights the needs, interest, and purpose of such a submission service mentioned in this study by the students and validated by teachers and parents.

- **Peer-to-peer evaluation -** This service is proposed in the context of new learning opportunities, in symbiosis with critical, positive, and constructive reflection that will enhance, in the classroom or outside the classroom, a more attentive behavior regarding disciplinary content. When critical exercises are carried out, the students are invited to participate and evaluate each other; however, critical thinking and attention may be a challenge, easily overcome with learning, training, and the opportunity to do so in a common collective work discussion process. Beware of the possibility of abuse or misinterpretation of the concept of peer evaluation, parents, in perfect agreement with teachers, recognize that "positive criticism" favors learning, values the student's work, and encourages continuation. The emphasis given to this new way of evaluating enhances attention, respect for colleagues, the "ease" of the students, uninhibition the shyer ones, as well as allowing to control those who speak more, nurturing positive criticism. This commitment of students to the peer evaluation process promotes critical, fair, and truthful thinking and not just evaluation for evaluation's sake or writing for writing's sake.
- **Personalized feedback to the student -** This very specific typology of feedback is not a common format of evaluation where positive criticism may favor learning by valuing the student's work and encouraging her/him to continue. This augments the possibility for the teacher to give much more efficient and assertive timely feedback with a comment about the student's work, explaining how it can be improved, as well as to follow the hetero-evaluation discussions. Both peer assessment and the teacher feedback that is suggested in this study consider that young people appreciate these interactions, and it is essential and pedagogical to allow them to do so.
- **Study management - A** study management element, associated with a notification service, would help students to be aware of the assignments and groupwork that is scheduled and plan what they must do accordingly. For example, the system could send a notification week before the day of an assessment exercise which should constitute an extra alert for the student to start studying for a certain subject. With this kind of management instrument, students will have more time to organize themselves in a more effective and attentive way. This should also avoid last-minute study and facilitate access to the content made available by the teachers and library/school ecosystem.

This model of infocommunicational services systematizes the most pertinent opinions, suggestions and proposals collected during this study and at a certain point of the research process, were validated by all the cohorts that integrated the population of the case study. Fig. 12 depicts the complexity of the holistic relation of all elements that integrate the infocommunicational heuristic model. As a research process it can be inspiring, a reference, and generalizable for other smart school ecosystems. The specific contributions of this educational community, as pertinent as they can seem, are only effectively applicable to the D. Maria II school cluster at Vila Nova de Famalicão, Portugal.

Although some of these services are not innovative, it is not common to see them being promoted in formal learning ecosystems, such as schools and integrated in the same infocommunicational platform. It was interesting to see that the students suggested some characteristics, to augment the common services, that can considerably improve sociability and empathy and contribute to a more humane learning context. The several approaches mentioned by the students and at a certain

point validated or highlighted by teachers and parents also augment the opportunity for collaborative and autonomous learning processes.

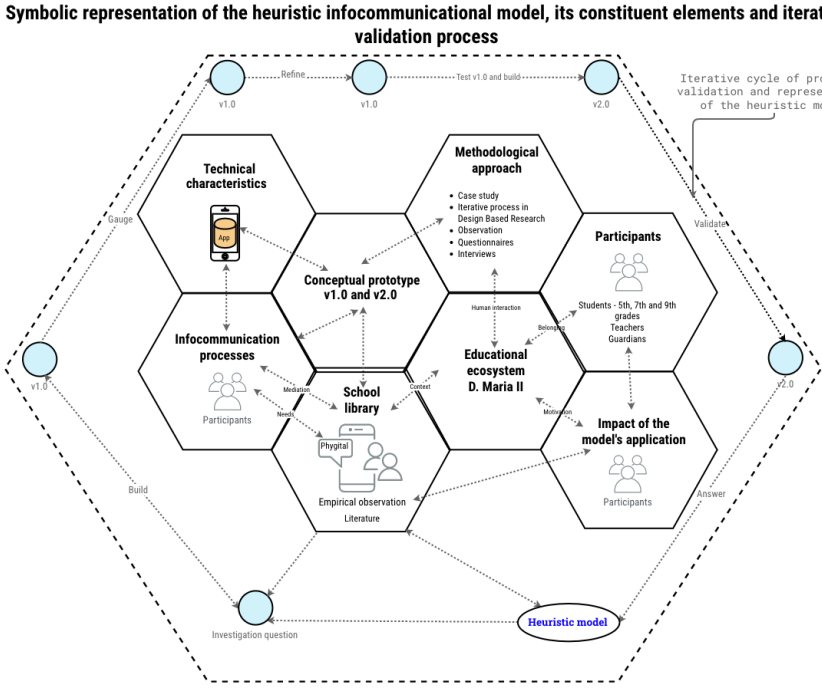

Fig. 12 Elements of the Infocommunicational heuristic model. Source [34, p, 359].

The heuristic infocommunicational model integrates several elements, inter-dependent as represented symbolically in figure 12, and all needed to design and substantiate the infocommunication services that are proposed for this very specific learning ecosystem – School Cluster D. Maria II at Famalicão, Portugal.

As depicted in figure 12 the model considers 8 elements or parts and informs their relations: the infocommunication services (described previously); School Library; Educational ecosystem; Participants (main stakeholders of the learning ecosystem); Methodological approach; Conceptual prototype; Technical characteristics; Model's influence (collection of data/results that shows relevance and pertinence of the model's application). These elements can be further detailed as follows:

Infocommunication services - Augment the development of student's learning autonomy and sociability. An element that is explained in the beginning of this section as one of the fundamental results and contributions of this heuristic model.

School library - Assumes a new configuration of technological mediation within the educational ecosystem, as an agent of change, with the librarian teacher as a fundamental actor

- Fosters the student – library relation
- Facilitates and manages change
- Highlights the Librarian teacher as a mediator
- Potentiates the Infocommunication services
- Content aggregator
- Promotes the "Student – Library" relation in Phygital space (Physical + Digital paradigm
- Support for teaching and non-teaching activities

Educational ecosystem - Mirrors a proximity format to leverage a more implicated positioning for all the stakeholders.
Educational offer in a very well identified socio- economic, and cultural, school (cluster) ecosystem

- Valuing the informal dimension complementary to the formal
- Relevance of the Disciplinary Departments
- Teaching and non-teaching staff
- Focus on Students - from 5^{th} to 9^{th} grades
- State of the Art Technological infrastructures
- Leveraging Human Interaction

Participants - Identifies and leverages empathic relationships between students, student-teacher, teacher-student, teacher-in-charge and vice versa.

- Students - 5^{th}, $7^{th,}$ and 9^{th} grades
- Teachers
- Parents

Methodological approach - Describes the scientific method (hybrid approach) and data collection techniques that are needed to implement the model and get the desired results. The methodological approach considered in this heuristic model, driven by a "Person-Centered" paradigm promotes interaction, collaboration, and reflection, experiential and critical reflection during the whole participatory research process. The coordinator of the research process, a mediator of all the participatory data gathering moments, must be someone accepted by the community. If this situation is not guaranteed or if at some point in the research this acceptance / confidence is compromised, the research process' performance and outcome will be affected.

- Case study
- Design-Based Research
- Observation
- Questionnaire with human mediation
- Semi-structured interviews

The Design-Based Research method as proposed by [27], [30] and improved by [31] continues to be extremely controversial in the scientific community that argue it is not a process capable of delivering value to design science. These opinions situate, at best, DBR as a design process capable of taking a product development strategy much beyond its market expectations. The authors argue otherwise and gathered empirical evidence that DBR, which includes a prototype iterative development strategy as an inquiry instrument, proved to have a direct impact in the community members during

the research process and capable of gathering innovative information. Besides the research results *per si*, directly related with the case study participants that provided sufficient information for the research team to propose an infocommunicational model, all participants shared the influence and impact of the participatory research process in their perspective of new media in educational ecosystems. This was obvious in some teachers that had a very specific opinion and behavior regarding smartphones and technology in the classroom before this research process and now reveal to be experimentalists and commonly use technology to setup experiences inside the classroom. The authors are comfortable to conclude that DBR was a facilitator of change in this community, namely amongst teachers, and capable of identifying innovative knowledge in this context of human activity. One of the limitations of DBR process could have been related to the mediation capacity of the research team inside the community. In fact, the research team members, if not members of the community, should plan a pre-engagement strategy with the case study community to guarantee social proximity, confidence, and empathy. In the context of the research reported in this paper this was not needed because the main researcher was a community member, a librarian teacher, recognized by all as an exemplary colleague and teacher due to her human and professional qualities. All in all, the data that was gathered contains evidence of opinion/qualitative convergence that led to the proposed heuristic model. This also confirms that the qualitative sample size was adequate for this educational ecosystem's social characteristics.

Technical characteristics - These technical details are identified directly from the student's narratives and should configure the technical platform that integrates the infocommunicational services. This alignment of technical specifications with the infocommunicational services' purpose is expected to put the students on a more attentive and interventional level, intuitively

- Students' proximity to new media
- Mobile and familiar device - "bring your own device" (BYOD)
- Smartphone and/or tablet

Conceptual prototype v1.0 and v2.0 - The prototype is proposed in this model as a research instrument to support inquiry and represents (simulates and/or demonstrates) the infocommunicational services at stake. This motivating and facilitating technical representation of a model's element allows peer evaluation and iterative stakeholder (students, teachers, and parents) feedback, in a formative and summative evaluation

- To support the participatory design and evaluation of Model v1.0 - infocommunication services
- Participatory design and evaluation of Model v2.0
- Participatory validation of model v2.0

Impact of the model's application - This element should integrate and disseminate a holistic view of the model's application influence in the learning ecosystem. The school librarian teacher should be a central actor in the coordination of this continuous monitoring and data collection, namely, access to the school library, as a phygital space (physical+digital), answering to the information and communication needs and interests of learning ecosystem's stakeholders – students, teachers and parents.

- Represents a Globalizing element
- Strengthens pedagogical ties
- Recognizes good practice and distinctive results
- Can include a Guidance manual
- Depicts technological mediation practice in the learning ecosystem as a whole.

6 Conclusions

The participatory research process gave rise to an infocommunicational model that was developed with the input of various stakeholders, including individuals both within and outside of the formal educational ecosystem, such as students, teachers, and parents. The heuristic model was comprised of deeply structured information pertaining to the comparison of social environments, specifically those found within the school and home settings, as well as those experienced both inside and outside the classroom. The heuristic model pertaining to infocommunication services assumes a valid nature due to its construction based on the experiential accounts of 236 community stakeholders who participated in the study. The adaptability of this tool could serve as a model for effective implementation in educational settings, fostering engagement, cooperation, and contemplation, encompassing practical and analytical perspectives. The widespread use of new media by students is a fact that needs to be considered as a technologically mediated support strategy. This is because new media usage by students can facilitate the growth of student autonomy in a way that is both functional and more effective.

Within educational ecosystems, the symbiotic link between democratic principles, collaborative efforts, and effective leadership among various educational stakeholders is an asset that contributes to the equitable distribution of resources and the development of expanded educational opportunities. Alluding to the school libraries, it is worth highlighting the constant concern to integrate all users in its purpose in a perspective of engagement, interaction and enhancing cooperation capable of stimulating the creation of innovative environments - it is crucial to reassess and restructure library services according to users' needs.

The task is to design innovative infocommunication structures that are easily accessible to all users and at the same time efficient, user-centric, and reliable. Proficiency in managing, optimizing, and leveraging diverse resources and channels is a crucial competence that individuals must possess to effectively access, investigate, and authenticate information. It is of utmost importance to maintain a conscientious, equitable, and evaluative approach to the management, optimization, and utilization of resources. The school library, as a phygital space that combines physical and digital resources, facilitates the support of stakeholders' needs and interests. The student is positioned as both a consumer and producer of information, as well as an agent of critical self and peer assessment. The capacity to promptly address classroom obstacles promotes student attentiveness and encourages active engagement. The librarian, serving as a catalyst for transformation, will actively engage with the desires and requirements of students, educators, and guardians. Through the implementation of novel forms of technological mediation,

the librarian will foster meaningful interactions with all members of the educational community, with a particular emphasis on students. The involvement of disciplinary department coordinators is crucial in facilitating the implementation of effective practices within the organic learning ecosystem, as it serves as a key driver for change. The nature of the model, which is innovative, highly empirical, and participatory, makes it possible for empathetic ties to be formed between students, teachers, student–teacher, and vice versa. These interactions pave the way for a new strategic way of thinking about school as a formal and informal learning ecosystem. Pedagogical bonds can be strengthened, and "relationships of trust" can be improved when teachers can deliver feedback that is consistent, clearer and efficient during formative and summative assessment.

The proposed infocommunication model satisfies the requirements of the present case study and has the potential to serve as a benchmark in other educational environments. The significance of this model applied in an empirical process within a specific context, delivered evidence that is relevant and useful for community at stake in this research. Moreover, this model also facilitated novel learning and opportunities within the classroom by leveraging the technological devices that are owned by the students, as exemplified in this study with smartphone usage. During the study, students, teachers, and families changed their opinions about the use of smartphones in education. This change was due to two factors:

(i) Appreciation of the adaptability of the equipment.

(ii) The fact that a researcher and a colleague explored smartphones in education.

First, the adaptability to distance learning. New practices emerged from the need to streamline distance learning with synchronous and asynchronous classes in an educational environment with limited technological resources. "I even used the smartphone, I couldn't turn on the camera" or "I had the computer and the smartphone, so I could talk to the students" or "at the beginning I tried everything, at least I learned" or "I already knew that the cell phone was an aid to teach the classes, I already used it before" are examples of how teachers need to find alternatives to maintain / augment the teaching and learning process.

The second aspect was initially unknown, and even those who had the knowledge also had some doubts. In the classroom, smartphones were banned. The research team's casual interaction with teachers from the educational ecosystem increased curiosity about the device, which helped to minimize this scenario. It was a moment of awareness and community outreach to build trust and get the first indicators of change due to smartphones. Some teachers who were more skeptical of mobile devices started saying "you can have your smartphone" to ease concerns and authorize. Those who had always supported the use of smartphones in and out of the classroom did so more enthusiastically. In an educational ecosystem where everyone knows about the research, engaged and curious instructors attended Phase 3 sessions numerous times. The engagement of the professors, who were virtually always in the library, was inspiring and resulted in positive comments, wanting to know when the app would be accessible. It encouraged face-to-face collaboration and interest. One of the teachers said, "She [the researcher] has been talking a lot, she has been spreading that seed around here, she is always spreading it, we already know it".

This framework, built on a new digital landscape, is meant to improve teaching, and learning by creating a more demanding, participative, and creative

synchronization. Demonstrating a new format of knowledge building and exploration, like [36], guides the "I" in a "digital transition" to dialogue, understand, and act on it. The creation of opportunities, active listening to diverse stakeholders, pursuit of solutions, iterative development, validation, and dissemination of knowledge are essential components for fostering innovation and sustainability within any educational ecosystem.

The present research was conducted under the coordination of a phygital (physical + digital) school library, with the active involvement of students in identifying their user eXperience/narratives (UX) mediated by smartphones, within the specific context of the D. Maria II school cluster in Vila Nova de Famalicão, Portugal. The study was based on infocommunicational constructs and yielded compelling evidence that this research process can foster novel learning opportunities for students while also enhancing their social, experiential, and reflective skills.

Acknowledgements. The research team expresses gratitude to the educational community of D. Maria II school cluster, Vila Nova de Famalicão, Portugal, including the students, teachers, and parents who participated in this case study. Their critical reflections, suggestions, comments, and valuable time dedicated to this cause are appreciated. A noteworthy recognition is extended to the team members who have contributed to the integration of the SMARTEES project. The present study acknowledges the contributions of Eleonor Silva, a master's student in Multimedia Communication, and Adriana Machado, Ana Beatriz Bastos, Irla Vaz, and Rejane Fernandes, who are all pursuing a bachelor's degree in New Communication Technologies at the University of Aveiro, Portugal. Additionally, we extend our gratitude to Cândida Pinto, Director of the D. Maria II school cluster at Famalicão, Portugal, for her facilitation and unwavering support throughout the research process. This work is financially supported by national funds through FCT – Foundation for Science and Technology, I.P., under the project UIDB/05460/2020.

References

1. MacLuhan, M. & Fiore, Q.: The Medium is the massage. Penguin Books. (1967)
2. Moeller, S., Ammu J., & Jesus Lau, T. C.: Towards Media and Information Literacy Indicators. Expert Meeting 4-6 November 2010, Bangkok, Thailand (2010) https://www.ifla.org/wp-content/uploads/2019/05/assets/information-literacy/publications/towards-media-and-Information-literacy-indicators.pdf
3. Cornella, A., & Cugota, L.: Educar Humanos num Mundo de Máquinas Inteligentes. Universidade de Trás-os-Montes e Alto Douro c/Apoio Fundação da Casa de Mateus (Programa Eco Mateus) (2019)
4. Nakamura, J., Csíkszentmihályi, M.: The concept of flow. In: Snyder, C.R., Lopez, S.J. (eds.) Handbook of Positive Psychology, pp. 89–105. Oxford University Press (2001)
5. Merchant, G.: Mobile Practices in Everyday Life: Popular Digital Technologies and Schooling. British Journal of Educational Technology, 43, 770 (2012) https://doi.org/10.1111/j.1467-8535.2012.01352.x
6. AASL.: Empowering Leadership for School Librarians (2018) https://www.ala.org/aasl/sites/ala.org.aasl/files/content/advocacy/statements/docs/AASL_Position%20Statement_Strategic%20Leadership%20Role_2018-06-24.pdf
7. Hughes, H., Bland, D., Willis, J., Burns, R.E.: A happy compromise: Collaborative approaches to school library designing. Australian Library Journal, 64(4), 321–334 (2015) https://doi.org/10.1080/00049670.2015.1033380

8. IFLA: Diretrizes da IFLA / Unesco para a biblioteca escolar. In C. P. da IFLA & Portuguese (Eds.), Library (Barbara Sc, Issue 2000, pp. 1–28) Rede de Bibliotecas Escolares (2016)
9. Conde, E.: Bibliotecas Escolares...porque sim! Redes, bibliotecas e literacias -Cidehus (pp. 1– 18) (2016) https://books.openedition.org/cidehus/2559
10. Nofal, E., Reffat, R.M., Moere, A.V.: Phygital heritage: an approach for heritage communication. Online Proceedings from the Third Immersive Learning Research Network Conference (2017) https://doi.org/10.3217/978-3-85125-530-0-36
11. UN.: "Sustainable Development Goals - SDG," 2015 https://www.un.org/sustainabledevelopment/
12. Chou, P.-N., Chang, C.-C., & Lin, C.: BYOD or not: A comparison of two assessment strategies for student learning. Computers in Human Behavior, 74, 63–71 (2017) https://doi.org/10.1016/j.chb.2017.04.024
13. Sampaio, D.: Do telemóvel para o mundo (2nd ed.). Caminho (2018)
14. Boyd, D.: É Complicado - As Vidas Sociais dos Adolescentes em Rede. Ed. Relógio D´Água Editores (2015)
15. Carvalho, A. A.: (org.) Apps para dispositivos móveis. In Dge (Vol. 95, Issue 44) (1998) https://erte.dge.mec.pt/sites/default/files/noticias/app_para_dispositivos_moveis.pdf
16. Alirezabeigi, S., Masschelein, J., Decuypere, M.: The Agencement of Taskification: On New Forms of Reading and Writing in BYOD Schools (2020) https://doi.org/10.1080/00131857. 2020.1716335
17. Scolari, A.: Introduction: from media literacy to transmedia literacy. In Teens, media and collaborative cultures. Exploiting teens' transmedia skills in the classroom (2018) http://transmedialiteracy.upf.edu/sites/default/files/files/TL_Teens_en.pdf
18. Silva, E.: Smartphones em Ecossistemas Educativos: co-design de um protótipo conceptual. [Universidade de Aveiro] (2021) http://hdl.handle.net/10773/31971
19. Machado, A., Bastos, A., Vaz, I., Fernandes, R.: SMARTEEs - Smartphones in Educational Ecosystems (2021) http://hdl.handle.net/10773/32320
20. Scolari, A.: Media ecology, transmedia literacy, and redesign of interfaces. Matrizes, 3(12), 129–139 (2018)
21. UNESCO.: Artificial intelligence in education (2019) https://www.unesco.org/en/digital-education/artificial-intelligence
22. OpenAI.: Briefly history of ChatGPT https://chat.openai.com [accessed Apr 20, 2023]
23. OpenAI Team. ChatGPT: Optimizing language models for dialogue. https://openai.com/blog/chatgpt/ , November 2022. [accessed Apr 20, 2023]
24. Moore, S., Huy, A., Bier. N., Domadia, T., Stamper, J.: Assessing the Quality of Student-Generated Short Answer Questions Using GPT-3. In Educating for a New Future: Making Sense of Technology-Enhanced Learning Adoption: 17th European Conference on Technology Enhanced Learning, ECTEL 2022, Toulouse, France, September 12–16, (2022) Proceedings, pages 243–257. Springer, (2022). https://doi.org/10.1007/978-3-031-16290-9_18
25. Yin R.K.: The Case Study Method as a Tool for Doing Evaluation Curr. Sociol., 40, pp. 121–137 (1992)
26. Remenyi D.: Case Study Research, Academic Publishing International Limited, (2012)
27. Hoadley C.M.: Methodological Alignment in Design-Based Research Educ. Psychol., 39, pp. 203–212 (2004)
28. Collins A.: Toward a Design Science of Education New Directions in Educational Technology. pp. 15–22. Springer Berlin Heidelberg, Berlin, Heidelberg (1992) https://doi.org/10.1007/978-3-642-77750-9_2
29. Brown A.L.: Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings J. Learn. Sci., 2, pp. 141–178 (1992) https://doi.org/10.1207/s15327809jls0202_2
30. Stickdorn M., Schneider J.: This is Service Design Thinking, BIS Publishers, Amsterdam, The Netherlands, (2011)
31. Ball J.: The Double Diamond: A universally accepted depiction of the design process, https://www.designcouncil.org.uk/our-work/news-opinion/double-diamond-universally-accepted-depiction-design-process/ (data accessed: 13 December 2022)
32. Banathy B.H.: Dynamics of divergence and convergence in Dubberly, H. (ed.) How do you Design: A compendium of Models. pp. 24–25. Dubberly Design Office, San Francisco, California (2008)

33. Fonseca M.J., Mealha Ó.: Student Smartphone Experience Narratives Mediated by the Phygital School Library for Learning Ecosystems in Dascalu, M., Marti, P., and Pozzi, F. (eds.) Polyphonic Construction of Smart Learning Ecosystems - Proceedings of the 7th Conference on Smart Learning Ecosystems and Regional Development. pp. 13–28. Springer (2023) https://link.springer.com/10.1007/978-981-19-5240-1_2
34. Pereira, M.J.G.F.: Biblioteca escolar na era digital: proposta de modelo infocomunicacional em contexto educativo. [Universidade de Aveiro] (2022) http://hdl.handle.net/10773/34941
35. Morin, E.: Introdução ao Pensamento Complexo (6th ed.) Edições Piaget (2017)