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Mobile App for Science Education: Designing the Learning Approach

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Abstract: This paper reports research work related to a wider study, aimed at developing a mobile app for Science Education in primary-school. Several studies reveal that Science Education can be improved by using technology, namely educational software. However, to promote a structured use of technology, innovative learning approaches must be designed for educational software. This paper aims to answer how the interaction between students and a mobile app for Science Education can promote students' scientific competences development and self-regulated learning. To achieve this, a learning approach was designed, combining the Universal Design for Learning principles, Inquiry-Based Science Education and the BSCS 5E – teaching model for Science Education designed by the *Biological Sciences Curriculum Study*, which results in the acronym of the model. The 5E is related to each phase of the model: Engagement; Exploration; Explanation; Elaboration; Evaluation. The proposed was based on a grounded, participatory, and user-centred approach, crossing literature contributions with data collected among primary-school teachers through the application of a questionnaire (n = 118). Data collected allowed deductions about the expected adequacy of the learning approach, according to Nieveen's criteria for high quality educational interventions. This adequacy was revealed through the teachers' conceptions about the potential impact of the conceptualized mobile app (i) to provide a comprehensive and practical Science Education learning; and (ii) to enhance students' scientific competences development and self-regulated learning. The paper aims to contribute to the design of an innovative learning approach in Science Education and to share it with other researchers since it can be expanded to other educational software.

Keywords: mobile application; Science Education; learning approach; scientific competences; Universal Design for Learning; Inquiry-Based Science Education; BSCS 5E; Educational Data Mining

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1. Introduction

The importance of Science Education is increasing within a more democratic, informed and enabled society, faced with the great challenges that the technological world brings to new generations [1–7]. For this reason, Science Education is advocated from the early years, especially in primary schools. Some of the main reasons pointed out for this are its potential (i) to help students to develop (new) ideas and to "make sense of the world", from what they hear and see in their daily lives; (ii) to promote opportunities for the clarification of students' (pre-)concepts and to confront these with scientific evidence; (iii) to avoid students' belated conceptual change, by testing their ideas through scientific experiences; and (iv) to promote and enhance positive attitudes towards Science, extending and/or amplifying the number of students who will pursue scientific careers, and, among others, decreasing the problem of the growing lack of girls' interest in Science [2,3,6,8,9]. In this regard, almost all European countries propose as main objectives (a) to improve students' understanding regarding the application of Science in real life; and (b) to strengthen Science

Education in schools in order to increase recruitment in areas such as Mathematics and Technology [4].

For the last 30 years, several authors and organizations have highlighted the importance of a deeper understanding of the potential and/or effectiveness of the different Science Education learning approaches, for instance, in students' scientific competences development [10,11]. Furthermore, in the last decade, many European countries have been promoting several actions and efforts to integrate Science Education in a more contextualized way, e.g., by supporting the development and maintenance of international networks and databases to share and provide free (digital) educational resources and practices [10]. Despite these initiatives, Science Education is far from assuming the same importance as such disciplines as mother tongue and Mathematics in primary school [4].

In European countries Science Education is taught as one general integrated subject in primary-school, based on the broad acceptance that in real life knowledge and practice are not split. This approach highlights the integration and iteration between knowledge and practice, between theory and action, purporting a meaningful and contextualized knowledge construction practice. This comprehensive approach relates scientific concepts to other disciplinary contents/subjects and can help the students to develop logical reasoning, critical thinking, and an integrated and extended knowledge of reality [11]. This can also potentially enhance students' interest, stimulating new ideas, questions, and the understanding of (new) complementary concepts based on personal experience and/or real situations.

Several studies reveal that Science Education can be improved by using technology, namely personal computers, smartphones, tablets and different types of educational software [12–19]. The increasing usage of technological devices is an international trend, underlined in several reports of the development and usage of digital educational resources such as mobile applications (mobile apps) [17,20–22]. In the last OECD report related to innovation in education, the importance of these devices in Science Education is underlined, namely to enhance the development of students' content and procedural knowledge [23].

In line with the above mentioned, this paper reports research work related to a wider study aimed at developing a mobile app for Science Education in primary-school. One comprehensive research question has been designed: *Which type of mobile app can promote primary-school students' scientific competences development and self-regulated learning?* To answer this, eight additional questions have oriented the wider study. The present paper is focused on one of those eight additional questions, related to the interaction between the students and the mobile app and how that can promote students' scientific competences development and self-regulated learning: *How can students interact with the mobile app and how can the mobile app respond in real time to students' interactions, simulating the teaching and learning process and promoting the students' scientific competences development and self-regulated learning?* To answer this question, a learning approach was designed, combining the Universal Design for Learning (UDL) principles, Inquiry-Based Science Education (IBSE) and the BSCS 5E (5E) – teaching model for Science Education designed by the Biological Sciences Curriculum Study, which results in the acronym of the model. The 5E is related to each phase of the model: Engagement; Exploration; Explanation; Elaboration; Evaluation. This approach was designed and validated by crossing literature contributions with data collected among primary-school teachers through the application of a questionnaire (n = 118). Among other aspects not reported in this paper, the questionnaire application allowed deductions about the expected adequacy of the proposed learning approach.

Our study aimed (i) to contribute to the design of innovative learning approaches [3,5,23] by combining the UDL principles, the IBSE and the 5E; and (ii) to contribute to (research in) Science Education by proposing a learning approach that can be expanded and/or applied to other digital educational solutions besides mobile apps, aiming at (a) to facilitate approaches to scientific concepts/topics/phenomena; and (b) to promote students' scientific competences development: scientific knowledge, skills and attitudes, with particular focus on self-regulated learning.

Because our research was developed in Portugal, based on the most recent published data, our study also aimed to contribute to enhance and promote innovative practices in Portuguese primary schools, regarding the following reported aspects [23]:

- Technology can promote students' scientific knowledge development, its application and deepening, promoting understanding of scientific concepts and procedures.
- Portugal is one of the three countries with a great percentage of students having access to computers and tablets and using them for educational purposes.
- Despite this, the use of technology for practicing skills and procedures in Portuguese 4th grade Science lessons has been declining.
- There is great potential in the use of computers and tablets in Science Education, including learning through games, simulations, and real time assessment.
- The use of simulations by 4th grade science students (9 to 10 years old) remains uncommon.

In the following sections, the authors present how the study was implemented (Section 2) and how it can contribute to the above aspects, namely by proposing an innovative literature-based learning approach (Section 3.1); and presenting the expected adequacy of the integration of the proposed digital educational resources in the mobile app (Section 3.2); the potential impact of the conceptualized mobile app (Section 3.3); and the expected adequacyof the proposed learning approach in promoting scientific competences development (Section 3.4).

2. Materials and Methods

Since the wider study aimed at the development of a mobile app according to the future end-users' needs and expectations, a participatory and user-centred design approach was adopted. At the same time, the mobile app development was research-based.

For this mixed approach, a research plan was conceptualized involving (i) scientific knowledge deepening; (ii) the collaboration between researchers, experts and future end-users; (iii) mixed methods; and (iv) interactive, cyclic and flexible phases of analysis, design, development, implementation, evaluation and revision.

This research plan resulted in a participatory framework proposal nested within the larger framework of Educational Design Research [24]. *Educational Design Research* revealed to be the most adequate methodological approach to the study rationale since it [25,26]:

- encompasses interactive and iterative phases: Preliminary research, Prototyping phase, and Assessment phase;
- comprises systematic and flexible processes of analysis, design, development, implementation, evaluation and revision;
- uses mixed methods;
- involves different participants in the study;
- aims to solve educational problems through scientific knowledge deepening and the development of educational solutions;

In line with the above, the study fits in with this methodological approach by:

- being developed according to the three previously mentioned phases;
- foreseeing different moments of analysis, design, development, implementation, evaluation and revision;
- using different techniques and instruments for data collection and analysis (e.g., questionnaire, focus group, document analysis);
- involving the collaboration of researchers, experts and future end-users (primary-school students and teachers) in different study phases/moments;
- resulting in different scientific products: frameworks, guidelines and the mobile app prototypes.

The present paper reports on the Preliminary research focused on the analysis and design of the proposed mobile app (see Figure 1), presenting and discussing a literature-based learning approach proposal and data collected among primary-school teachers through the application of a questionnaire (n = 118).

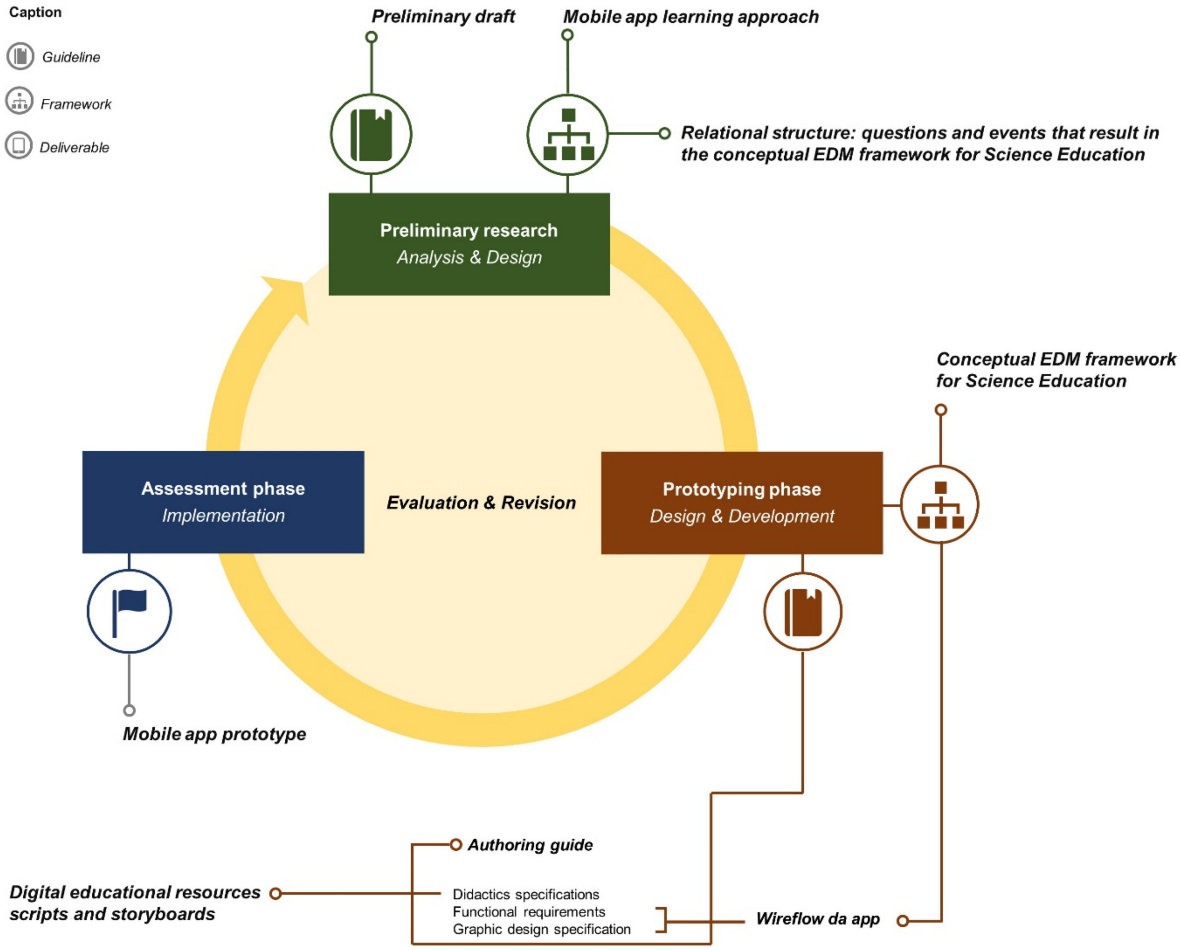

Figure 1. Conceptual scheme of the wider study.

Data collected with the questionnaire application was used in other moments of the wider study (e.g., to define the mobile app's target audience, i.e., 4th grade primary-school; to define the topic to be approached in the mobile app, i.e., the Human Body). In the study, data collected via the questionnaire allowed deductions about the expected adequacy of the proposed learning approach and the potential impact of the conceptualized mobile app.

Since the mobile app's learning approach is quite comprehensive, for its design four correlated moments within the Preliminary research were considered:

- Analysis, definition and combination of the theoretical frameworks that sustain the mobile app's learning approach: UDL, IBSE and 5E;
- Definition of the types of digital educational resources and learning management components integrated in the mobile app, and their relationship with the mobile app's learning approach rationale;
- Data collection, comprising the design, validation and application of the following questionnaire: *Primary-school teachers' conceptions about their knowledge and their educational practices in Science Education using digital educational resources* [27];
- Data analysis and discussion, with the production of the guideline *Preliminary draft*, that allowed the definition of the proposed mobile app: (i) target audience – 4th grade primary-school students; (ii) Science Education topic approached in the mobile app – the Human Body; (iii) digital educational resources to integrate in the mobile app – animations, games, simulations, quizzes and information areas; (iv) learning approach; and (v) learning management components – formative feedback, recommendations and real-time help triggered by the mobile app according to an Educational Data Mining (EDM) framework developed for the mobile app that derives from the authors'

preliminary proposal of the conceptual EDM framework for Science Education – *Relational structure: questions and events that result in the conceptual EDM framework for Science Education* [28].

All the study phases were implemented in Portugal, the country where the authors developed their research. For this reason, the questionnaire and the original data are only available in Portuguese [27,29].

2.1. Participants

Since teachers represent one of the most legitimate and reliable sources of information regarding the teaching and learning process, to ground and validate the proposed learning approach the authors opted to involve teachers in the Preliminary research reported in this paper.

Since the aim was to survey primary-school teachers' conceptions about their knowledge and their educational practices in Science Education using digital educational resources, the study sample was a convenience sample [29,30]. This option was to assure that most of the teachers answering the questionnaire used technological resources to teach Science Education. The study's population profile was the following: *Primary-school teachers that use and/or frequently interact with digital educational resources to teach Science Education.*

To select our sample, the authors first surveyed teachers with the mentioned profile. For this, Portuguese open access repositories dedicated to Science Education on the web that included registered primary school teachers were searched. From the search, the authors were able to find an open access repository in Portugal with these requirements: *House of Sciences* – originally *Casa das Ciências* [10].

This repository delivers digital educational resources in subjects such as Introduction to Science, Biology, Physics, Geology, Mathematics and Chemistry, allowing teachers to upload, share, access and/or download the following digital educational resources: animations, simulations, videos, interactive presentations, games, interactive whiteboard resources, documents, and activities exploration guides. According to the House of Sciences stakeholders, at the time of the survey the repository had 1046 primary-school teachers registered. From those, 118 primary-school teachers answered the questionnaire.

2.2. Data Collection

The paper reports on the Preliminary research, focused on analysis of the mobile app's requirements and design, presenting and discussing a proposal for a literature-based learning approach and data collected among primary-school teachers through the application of a questionnaire (n = 118).

The questionnaire was a multidimensional and *a priori* structured instrument, crossing four instruments validated and implemented in national and international settings. The authors adapted and adopted ten items and conceptualized another six. For this, the following stages were considered: (1) design of the pilot version of the questionnaire; (2) validation of the pilot version (3) implementation of the pilot version; (4) analysis of the data gathered; (5) design of the final version of the instrument; and (6) implementation of the final version.

Regarding the adapted item, the following instruments were used: Avaliação do Impacte Programa de Formação de Professores do 1.º Ciclo do Ensino Básico em Ensino Experimental das Ciências nas práticas docentes de ensino experimental (Evaluation of the Impact of the Primary-School Teachers Training Programme in Experimental Science Teaching on the Teachers' Practices) [31]; and TIMSS 2015 Grade 4 Teacher Questionnaire [32]. For the adopted items, the following instruments were considered: Self-Efficacy Teaching and Knowledge Instrument for Science Teachers [33]; and Survey of Preservice Teachers' Knowledge of Teaching and Technology [34]. A formal consent was requested of the instruments' authors, both to translate and to apply the adopted items.

According to the proposed and adopted methodology presented in Section 2 and Nieveen's criteria [35], in the Preliminary research teachers' conceptions provided assumptions about the expected adequacy of the proposed learning approach regarding its (a) consistency; (b) expected practicality; and (c) expected effectiveness (see Table 1).

Table 1. Nieveen's criteria for high quality educational interventions [35] (p. 94).

Criterion	
Relevance (also referred to as content validity)	There is a need for the intervention and its design is based on state-of-the-art (scientific) knowledge.
Consistency (also referred to as construct validity)	The intervention is "logically" designed.
Practicality	Expected: The intervention is expected to be usable in the settings for which it has been designed and developed.
	Actual: The intervention is usable in the settings for which it has been designed and developed.
Effectiveness	Expected: Using the intervention is expected to result in desired outcomes.
	Actual: Using the intervention results in desired outcomes.

The questionnaire's application was authorized and supported by House of Sciences stakeholders, by sending an e-mail containing the invitation to participate in the study and the hyperlink to the questionnaire to all the possible participants (N = 1046). In this way, it was assured that only primary-school teachers registered in the repository participated in the study, and allowed to control the number of e-mails read to reinforce the invitation if needed.

The instrument was implemented using the *University of Aveiro Questionnaires* platform [27] and it was available for 38 days. Besides the first e-mail containing the invitation sent on 27 February 2017, the House of Sciences stakeholders sent two more e-mails to reinforce the participation on March 13th 2017 and on April 3rd 2017.

The instrument was validated by five external experts and by the *Portuguese School Surveys Monitoring* team – originally *Monitorização de Inquéritos em Meio Escolar* (MIME). The preliminary pilot version of the instrument was sent to the external experts, who analysed it with a qualitative approach. Based on their appreciation, a convergence analysis was adopted [36]. Considering the consensus of comments, suggestions, points of view and ideas pointed out by the experts, the final pilot version of the instrument was generated and submitted for the MIME's validation and approval to be implemented in a school setting. Once approved, the questionnaire was implemented among a random sample of primary school teachers, according to the defined profile (n = 17).

The final version of the questionnaire comprised nine questions (Q). On the first page, the study and some clarifications about the instrument were presented, such as the normal duration of time to fill it in (around eight minutes). The second page was related to participants' informed consent and agreement to participate in the study. The third page comprised two questions, one Likert scale with eight items related to the teachers' knowledge and educational practices in Science Education (Q1); and one dichotomous "Yes/No" question asking the participants if they used digital educational resources to teach Sciences (Q2). By answering "Yes" the participants proceeded with the remaining questions (pages four and five), and by answering "No" the participants move to Q7 (page five).

The fourth page had four questions, all closed-ended one-choice or multiple-choice questions: Q3 related to the frequency of usage of digital educational resources; Q4 related to which school grades were most privileged to use them; Q5 related to the most used digital educational resources; and Q6 related to the usage of digital educational resources in Science Education (e.g., explore concepts/topics using games).

Finally, the fifth page comprised three questions. The first two were closed-ended multiple-choice questions: Q7 related to the Experimental Science Education topics most commonly explored by teachers, and Q8 related to the two topics most easily explored using digital educational resources. The last question (Q9) was an open-answer question related to the potential of the conceptualized mobile app.

Because the questionnaire was implemented in Portugal, the adopted items of the Q1 scale [36,37] were translated into Portuguese. To assure the correct version of the translation, the items were submitted to a process of translation and back translation, ensured by two external experts. To assure the internal consistency and reliability of the questionnaire, as mentioned, a pilot version of the instrument was applied to 17 primary-school teachers, allowing its validation. For both the pilot and the final version of the instrument, the adequacy of the sample, the internal consistency, and the reliability was verified [37–45] (see Table 2).

Table 2. Measures of the internal consistency and reliability of the questionnaire.

		Cronbach's α		Pearson's Coefficient
Pilot version	Knowledge	0.76	0.86	0.63 *
	Educational practices	0.89		
Final version	Knowledge	0.79	0.87	0.71 *
	Educational practices	0.82		

* $p < 0.01$.

In the present paper, to deduce the expected adequacy of the proposed learning approach, revealed through the teachers' conceptions about the potential impact of the conceptualized mobile app (i) to provide comprehensive and practical Science Education learning; and (ii) to enhance students' scientific competences development and self-regulated learning, from the nine questions available in the questionnaire, data from the teachers' answers to Q5, Q6, and Q9 were considered:

- Q5–*From the following options, please select the digital educational resources you frequently use in Science lessons using computers (including tablets)*.
- Q6–*From the following options, please tell us how you use digital educational resources in Science lessons*?
- Q9–*If you had a set of digital educational resources related to each other in a single mobile app (e.g., an animation, a game, and a simulation related to liquid float), would you use it to explore the areas mentioned above? Why*?

By asking the participants if they use digital educational resources to teach Science (Q2) the sample was split into two independent groups: group one–*Primary-school teachers that use digital educational resources to teach Science*, and group two–*Primary-school teachers that do not use digital educational resources to teach Science.* Q2 data analysis, verified that only 20.3% of the teachers did not use digital educational resources. This result confirmed the adequacy of the convenience sample, and collected significant data from which to infer the expected adequacy of the proposed learning approach.

From 230 answers to the questionnaire, 78 were incomplete and 34 were not properly saved in the *University of Aveiro Questionnaires* platform due a system failure. For these reasons, 118 complete and valid answers were considered, which will be analysed in the following sections for the three questions.

2.3. Data Analysis

For Q5 and Q6–closed-ended multiple-choice questions–descriptive statistical analysis was applied, using the software SPSS Statistics 24® (IBM Corporation, Armonk, NY, USA). Descriptive statistical analysis was conducted to deduce (i) the expected adequacy of the integration of the proposed digital educational resources in the mobile app; (ii) the potential impact of the conceptualized mobile app; and (iii) the expected adequacy of the proposed learning approach to promote scientific competences development.

For Q9–open-answer question–content analysis was conducted using the software webQDA® (Universidade de Aveiro, CIDTFF–Research Centre on Didactics and Technology in the Education of Trainers, Micro I/O, and Ludomedia). Content analysis was conducted to deduce the potential impact of the conceptualized mobile app and its potential future usage, namely regarding the expected adequacy of the proposed learning approach. For this, a deductive system of categories was designed to analyse the teachers' answers. The system of categories was designed according to the "User Experience Honeycomb" [46], reflecting the theoretical frameworks adopted (UDL, IBSE and 5E) and the proposed learning approach (see Table A1–Appendix A).

The system of categories was framed in the content analysis software by creating a project with the defined categories organized in a coding scheme, and with the data sources: teachers' answers to Q9 organized by identifiers (ID) [47]. The IDs were analysed according to the categories. To assure the adequacy of the system of categories and the coded IDs, clone versions of the project were submitted for experts' validation. For this, two external experts coded 10% of the coded ID selected randomly. Then, the coded ID were crossed and the reliability (r) of the system of categories was calculated according to the following [48]: $r = \frac{Ta}{(Ta+Td)}$, where TA represents the total of agreements and Td the total of disagreements between the researchers' coded ID and the experts. By applying this validation approach, the system of categories' reliability was verified (r = 0.73). Although the value is low [44,45,49–51], according to DeVellis [51] in some Social Sciences studies, namely those with a small sample such as the present one, reliability values from 0.6 can be considered as acceptable. For this reason, r = 0.73 was considered acceptable to proceed with the system of categories application.

To deduce the expected adequacy of the proposed learning approach, aspects related to the *User Experience –Valuable* subcategory and the aspects related to the *Scientific Competences* category were analysed, finding for both a total of 387 references. The original references were translated into English, bearing in mind textual coherence. Although some of the translated sentences suffered small adjustments, semantic, idiomatic, cultural, and conceptual equivalence were preserved.

3. Results

3.1. Literature-Based Learning Approach Proposal

The proposed learning approach designed for the mobile app combines the Universal Design for Learning (UDL) principles, the Inquiry-Based Science Education (IBSE) and the BSCS 5E (5E). UDL is an educational framework focused on the development of learning environments, designed to meet individual learning differences and to promote and facilitate the learning process [52,53]. Therefore, UDL proposes that the curriculum must be designed to promote equal learning opportunities, since information access is not enough for students' knowledge development [54]. Knowledge construction will depend on several aspects, such as learning goals, teaching and learning approaches, educational resources adopted and learning assessment methodology [53]. In this regard, UDL sets three main principles presented as follow according to the study scope [53–55]:

- Promote multiple means of (information) representation–the "what" of learning: to allow students to explore the same educational content in several ways;
- Promote multiple means of expression (and interaction with the information)–the "how" of learning: to allow students to explore flexible alternatives for performance and knowledge assessment;
- Promote multiple means of engagement–the "why" of learning: to allow students to explore challenging ways to contact with difficult concepts/topics, helping them to maintain interest and persistence in learning.

Regarding the theoretical frameworks adopted towards the teaching and learning process simulated by the mobile app, in the last decade several authors have implemented the IBSE approach according to the 5E inquiry curriculum model [1,56,57]. Both approaches propose five highly related phases, adopted in the study according to two complementary points of view:

(i) IBSE–Teachers' point of view: teachers' role in the learning process simulated by the mobile app [28,55]
  - Orientation phase: to stimulate students' curiosity about a certain scientific concept/topic;
  - Conceptualization phase: to confront students' (pre-)concepts and/or inquire about them, and to promote the generation of new ideas/assumptions;
  - Investigation phase: to lead the students to plan and apply investigation processes (e.g., collect, analyse and interpret data to test the assumptions);
  - Conclusion phase: to lead the students to draw conclusions by comparing/confronting their (pre-)concepts with new evidence;
  - Discussion phase: to confront students' ideas and/or results, promoting a reflection and learning process (self-)evaluation - this phase is adopted as transversal to the previous phases).

(ii) 5E–Students' point of view: students' learning process by interacting with the mobile app [28,56]
  - Engage phase: to stimulate students' interest and promote their personal and active learning involvement;
  - Explore phase: to lead the students to build their own understanding about concepts/topics, by confronting and experimenting with scientific phenomena;
  - Explain phase: to promote the students' opportunity to communicate their knowledge/findings and to establish a theoretical framework;
  - Elaborate phase: to lead the students to apply their (new) knowledge, deepening scientific concepts/topics and/or proceeding towards new learning paths;
  - Evaluate phase: to help students to develop self-awareness about their learning path and about their knowledge construction (this phase is adopted as transversal to the previous phases).

Besides the intrinsic relationship between both approaches found in the literature and the proposed complementary points of view endorsed for each one, their simultaneous adoption aims to address the importance of comprehensive and practical activities in the development of scientific competences [2,58–60]. Thus, the proposed mobile app first allows the students to contact (new) scientific concepts/topics and/or confront their previous knowledge, hoping that such confrontation will allow them to become actively engaged in reflective, exploratory and (self-)evaluative activities. For this, the mobile app integrates five types of digital educational resources, organized according to learning sequences (the mobile app games levels) and three learning management components.

Both the learning sequences and the learning management components are supported by an Educational Data Mining (EDM) framework integrated in the mobile app, according to the adopted methods and techniques. So that the mobile app can provide formative feedback, recommendations and real-time help and tailored to the students' needs, the app will need to provide (in terms of computer programming) a structure that allows the system (the mobile app) to read every single interaction between students and the mobile app (and *vice versa*). For this, as presented in Figure 1, in the Preliminary research the authors have also defined which questions should be "asked" of the system and which events should be read and analysed through the EDM methods and techniques. The set of questions and events resulted in the so-called *Relational structure: questions and events that result in the conceptual EDM framework for Science Education* [28]. The *Relational structure* is based on the learning approach proposed, relating it to the possibility of the mobile app (i) to assess in real-time students' performance levels; (ii) to identify in real-time difficulties experienced by the students; and (iii) to guide students in real-time students along the most adequate learning path [61].

The EDM framework and its influence on the availability of digital educational resources and learning management components aims to simultaneously promote the students' development of scientific competences–scientific knowledge, skills and attitudes–and self-regulation with regard to attitudes [1,62–67] (see Figure 2). Thus, the mobile app includes several game levels related to different scientific concepts/topics. Each level supports a learning sequence organized according to the following digital educational resources: animation, game, simulation, quiz, and information areas. The integration of these resources reflects the relationship between the UDL principles and the theoretical frameworks adopted [68–77] (see Table 3).

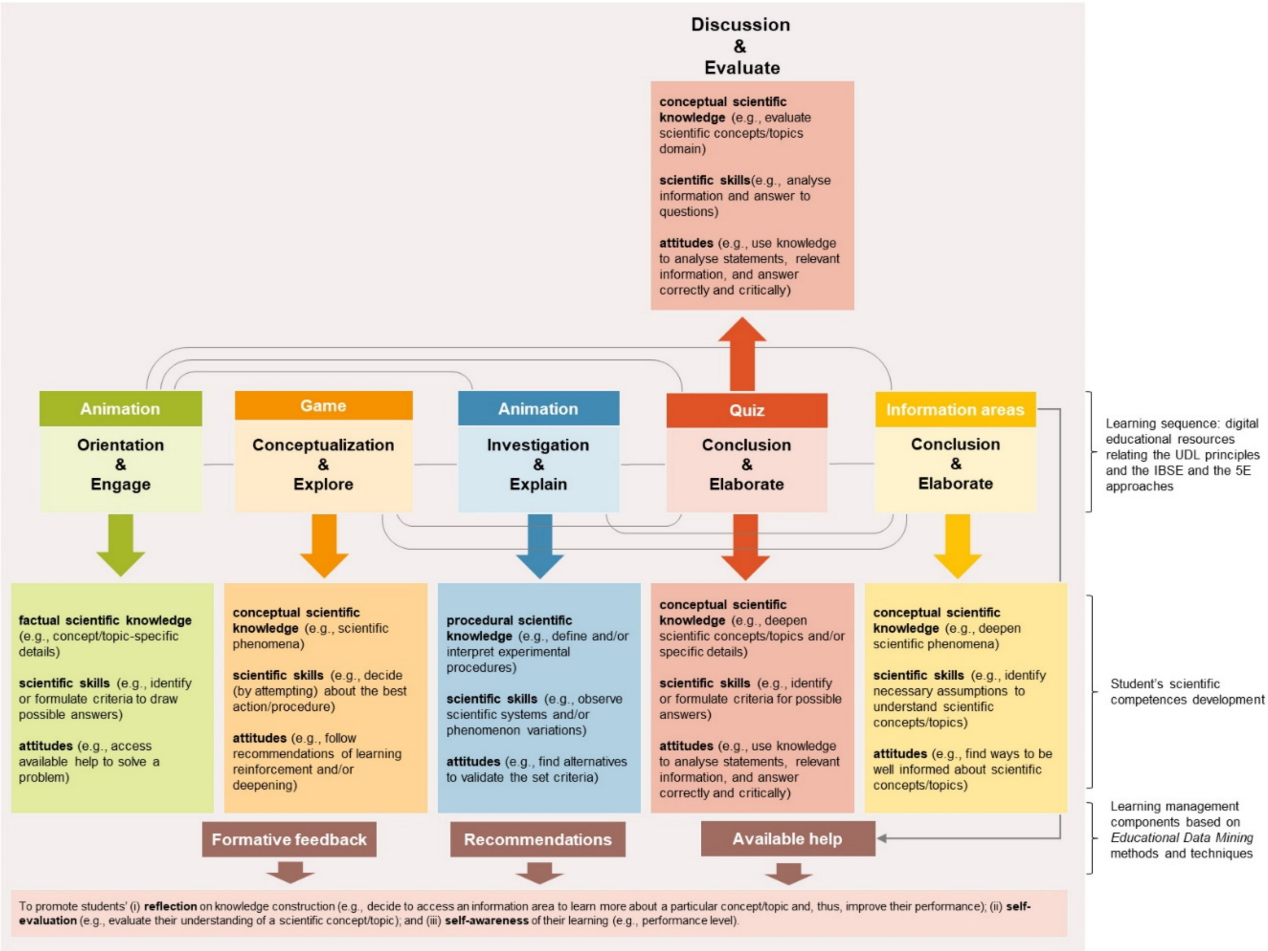

Figure 2. Proposed learning approach scheme.

Table 3. Relationship between the five types of digital educational resources and the three learning management components integrated in the mobile app with the UDL principles, the IBSE and the 5E approaches, and the student's scientific competences.

UDL	IBSE	5E	Scientific Competences
Watch and explore (interactive) animations			
As a means of scientific information representation, enhancing the introduction and presentation of scientific concepts/topics	Orientation - to stimulate students' curiosity about a particular concept/topic - to promote students' self-evaluation about previous knowledge	Engage - to draw students' attention/interest - to involve students in a personal way - to stimulate students to predict, relate and evaluate their previous knowledge	To help the students to develop - factual scientific knowledge (e.g., concept/topic-specific details) - scientific skills (e.g., identify or formulate criteria to draw possible answers) - attitudes (e.g., access available help to solve a problem)

Table 3. *Cont.*

UDL	IBSE	5E	Scientific Competences
		Explore games	
As a means of engagement (expression, and interaction with the information), enhancing the exploration of scientific concepts/topics	Conceptualization- to lead the students to form assumptions- to test students' assumptions according to the established dynamics through inquiring	Explore - to promote students' active learning - to stimulate students to analyse information, observe and compare phenomena, variables and concepts - to help students to identify requirements and variables that influence outcomes - to help students to interpret results - to stimulate students to draw and confront conclusions	To help the students to develop - conceptual scientific knowledge (e.g., classes, categories, principles, systems and scientific phenomena) - scientific skills (e.g., decide (by attempting) the best action/procedure) - attitudes (e.g., follow recommendations for learning reinforcement and/or deepening)
		Explore simulations	
As a means of expression (and interaction with the information), enhancing the application of scientific knowledge and skills	Investigation - to lead the students to form assumptions, to plan processes, to test assumptions, and to collect, analyse and interpret data	Explain - to stimulate students' reflection about how they structure their conceptual framework and the designed research path - to help students to draw conclusions and structure their knowledge - to lead the students to confront their initial ideas with the results of the experimental activity - to help students to establish a theoretical framework - to help students to establish relationships between their choices and the initial research question	To help the students to develop - procedural scientific knowledge (e.g., define and/or interpret experimental procedures) - scientific skills (e.g., observe scientific systems and/or phenomenon variations) - attitudes (e.g., find alternatives to validate the set criteria)
		Answer quizzes	
As a means of expression, enhancing the deepening of scientific knowledge and skills	Conclusion - to lead the students to draw conclusions - to help students to reflect about how they construct their knowledge	Elaborate - to promote students' knowledge mobilization - to help students to discover and understand the implications of the phenomena explored - to help students to establish relationships with other concepts/topics	To help the students to develop - conceptual scientific knowledge in order to deepen their knowledge (e.g., deepen scientific concepts and/or specific details related to the concept/topic addressed) - scientific skills (e.g., identify or formulate criteria for possible answers) - attitudes (e.g., analyse statements and (ir)relevant information)
		Evaluate - to lead the students to evaluate their understanding of a scientific concept/topic - to lead the students to apply their (new) knowledge - to lead the students to deepen their conceptual framework or advance towards new research paths	To help the students to develop - conceptual scientific knowledge in order to assess knowledge (e.g., verify the domain of scientific concepts) - scientific skills (e.g., interpret statements and answer questions) - attitudes (e.g., use their knowledge to analyse statements, seek relevant information, and answer correctly)

Table 3. *Cont.*

UDL	IBSE	5E	Scientific Competences
Explore games			
Access information areas/available help			
As a means of scientific information representation, enhancing the deepening of scientific knowledge and skills, and helping the students to proceed in their learning path	Conclusion & Elaborate - to lead the students to deepen/expand their knowledge - to help students to clarify doubts		To help the students to develop - conceptual scientific knowledge (e.g., deepen scientific phenomena) - scientific skills (e.g., identify necessary assumptions to understand scientific concepts/topics) - attitudes (e.g., find ways to be well informed about scientific concepts/topics)
Read formative feedback and accept recommendations			
As a means of engagement, enhancing the students' interest and persistence in learning process	Discussion - to reinforce/deepen students' knowledge - to help students to self-regulate their learning (e.g., what content to explore)	Evaluate - to lead the students to constantly and continuously be aware about how much they have learned and how their conceptual framework evolved - to help students to a greater understanding of the scientific competences developed - to help students to find ways of self-correction and readjustment	To promote students' - reflection on knowledge construction (e.g., decide to access an information area in order to learn more about a particular concept/topic and, thus, improve their performance) - self-awareness of their learning (e.g., performance level)

The integration of animations aims at the representation of scientific information, enhancing the introduction and presentation of scientific concepts/topics. By integrating games, the authors intend to provide means of engagement, expression, and interaction with the information, enhancing the exploration of scientific concepts/topics. The simulations intend to be a means of expression and interaction with the information, enhancing the application of scientific knowledge and skills. By integrating the quizzes, the authors aim to provide a means of knowledge expression, enhancing the deepening of scientific knowledge and skills. Finally, by integrating information areas the authors intend to provide means of scientific information representation, enhancing the deepening of scientific knowledge and skills, and helping the students to proceed in their learning path.

As referenced, besides the integration of digital educational resources, the mobile app includes three components related to the learning management process: available help, formative feedback, and recommendations. As mentioned, these components are related to the authors' proposal of an EDM framework for Science Education integrated into the mobile app, aiming simultaneously at students' development of scientific competences, and at students' self-regulation: reflection, (self-)evaluation and self-awareness [28]. The focus on self-regulation aims that the students are able to (i) to identify personal interests and learning needs; (ii) set learning objectives and pathways according to personal interests and needs; and (iii) search for personal skills consolidation and deepening learning opportunities.

Regarding the IBSE and the 5E approaches, the mobile app game levels (the learning sequences) and the learning management components allow the students to go through the five phases of the adopted approaches by exploring scientific concepts/topics of introduction, exploration, application and deepening activities. Each level is related to a specific scientific concept/topic which means that the level related to "A" comprises one animation, one game, one simulation, one quiz, and information areas related to "A"; the level related to "B" comprises one animation, one game, one simulation, one quiz, and information areas related to "B"; and so on.

According to the proposed learning approach scheme (see Figure 1) and the previous examples, for instance, the students can begin to explore game "A", continue to animation

"A", browse an information area "A", answer quiz "A" and explore the simulation "A2; or the students can run each learning sequence: animation "A" → game "A" → simulation "A" → quiz "A" → information areas "A". The mobile app is set to propose this last sequence of exploration, so the student can go through the theoretical learning structure proposed. However, to allow the students to set learning objectives and pathways according to personal interests and needs, and to promote the students' development of self-awareness about their learning path and their knowledge construction (5E Evaluate phase), the mobile app allows students to explore each learning sequence both linearly and non-linearly. To ensure that all the phases are completed, students can only advance to the next level (learning sequence) when they complete the previous one.

Thus, either exploring the mobile app linearly and/or non-linearly, students will have the opportunity to develop scientific knowledge (factual, conceptual and procedural), scientific skills and attitudes by exploring the five types of digital educational resource. In addition and simultaneously, the three learning management components will ideally help to promote the development of students' scientific competences and self-regulated learning, since the mobile app (i) gives the students the opportunity to choose what digital educational resources are more suitable for their learning path, and so to personalize it; and (ii) supports students' digital educational resources exploration by giving them real time formative feedback and recommendations, and identifying when they need help (e.g., to propose that the students access available help to solve a problem).

In the following section, data analysis from primary-school teachers' answers to the questionnaire (n = 118) detail the expected adequacy of the proposed learning approach.

3.2. Expected Adequacy of the Integration of the Proposed Digital Educational Resources in the Mobile App

For Q5 and Q6 descriptive statistical analysis was applied, calculating percentages according to the total sample.

As presented above, the proposed learning approach provides learning sequences–the mobile app game levels. Each level has a set of five correlated digital educational resources: an animation, a game, a simulation, a quiz and information areas. To deduce the expected adequacy of the integration of these types of digital educational resources in the mobile app, the teachers' answers to Q5 were analysed: *From the following options, please select the digital educational resources you frequently use in Science lessons using computers (including tablets).* From the listed resources, the most frequently used by teachers in their Science lessons were animations (68.6%) and games (55.9%) (see Figure 3).

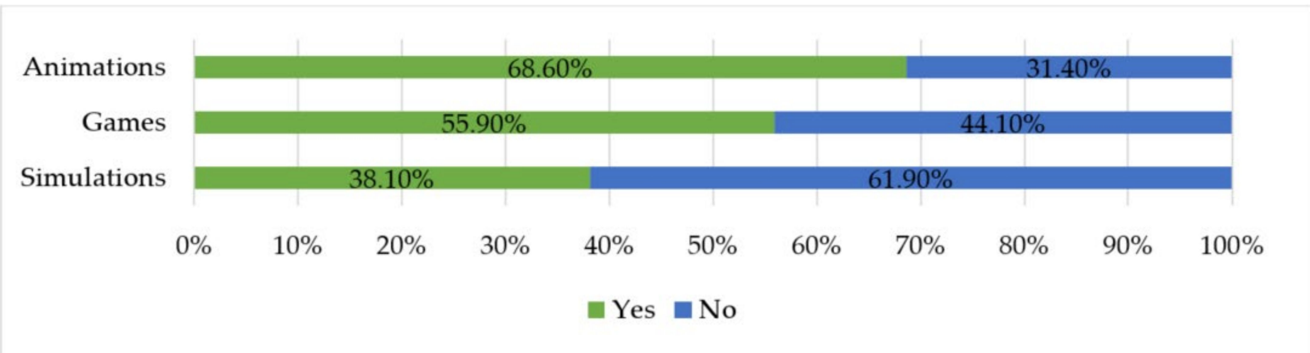

Figure 3. Primary-school teachers' conceptions about the digital educational resources most frequently used in their Science lessons using computers (including tablets) (n = 118).

To deduce the expected adequacy of the usage of the listed digital educational resources to introduce, explore, apply, and/or deepen scientific concepts/topics, data gathered from Q6 was analysed: *From the following options, please tell us how you use digital educational resources in Science lessons?* The analysis demonstrated that teachers used mainly animations to introduce scientific concepts/topics (57.6%); simulations to explore scientific concepts/topics (45.8%); games to apply scientific concepts/topics (52.5%); and simulations to deepen scientific concepts/topics (39%) (see Figure 4.)

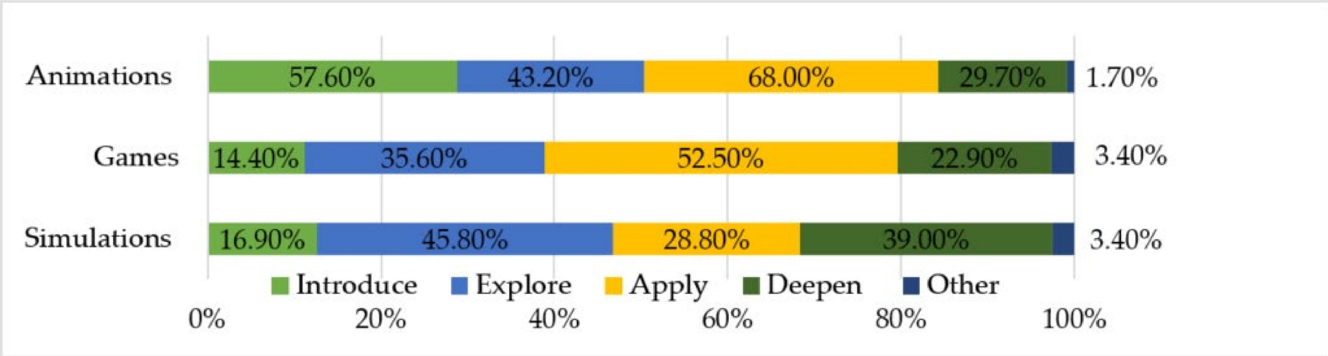

Figure 4. Primary-school teachers' conceptions about how they use digital educational resources in Science lessons (*n* = 118).

Finally, the proposed integration of digital educational resources in the mobile app, aiming at scientific concepts/topics' introduction, exploration, application and deepening according to UDL principles (see Table 3), was matched with the collected data (see Table 4).

Table 4. Proposed integration of the digital educational resources vs. Teachers' conceptions about the expected adequacy of the usage of the listed digital educational resources (*n* = 118).

	Introduce Scientific Concepts/Topics	Explore Scientific Concepts/Topics	Apply Scientific Concepts/Topics	Deepen Scientific Concepts/Topics
Proposed digital educational resources	Animations	Games	Simulations	Quizzes Information areas
Teachers' conceptions about the expected adequacy of the usage of the listed digital educational resources (%)	Animations (57.6%)	Simulations (45.8%)	Games (52.5%)	Simulations (39%)

3.3. Potential Impact of the Conceptualized Mobile App

Regarding the *User Experience –Valuable* subcategory, data analysis demonstrated that most of the teachers privileged a mobile app providing digital educational resources correlated with the possibility of implementing *Orientation* and *Engage* phases, and to promote scientific information *Representation* (66 references registered). The teachers' answers revealed the following aspects related to the potential of the mobile app to:

- represent a means to obtain and/or to appeal to students' interest, stimulating them to learn (e.g., "to stimulate learning process"–ID 116);
- enhance students' interaction with scientific contents/topics, promoting a more dynamic, meaningful and comprehensive learning process (e.g., "more appealing and interactive, getting more easily the students' attention and promoting a more meaningful learning"–ID 188);
- facilitate information presentation and exploration (e.g., "allows to present/explore concepts easily"–ID 219);
- enhance scientific concepts/topics observation and/or exploration, promoting opportunities for students to apply and/or evaluate their knowledge (e.g., "observe, inform, apply and evaluate knowledge"–ID 57);
- facilitate a comprehensive, systematic, interdisciplinary and "hands-on" scientific concepts/topics/phenomena approach (e.g., "global, interdisciplinary, and applied vision of the phenomena"–ID 66);
- promote students' motivation to learn more (e.g., "to enhance student's motivation to discover and learn more"–ID 170).

For the aspects related to the potential of the mobile app to implement *Conceptualization* and *Explore* phases, and to promote *Engagement*, *Expression*, and interaction with scientific concepts/topics, 29 references were registered in teachers' answers. The references emphasized aspects related to the potential of the mobile app to promote:

- students' active and playful learning (e.g., "learn by doing"–ID 167);
- the development, consolidation and deepening of scientific knowledge (e.g., "to materialize concepts, to consolidate knowledge and to promote a better perception of reality"–ID 50);
- different approaches to apply scientific competences (e.g., "exploring and deepening (scientific knowledge) using games and simulations–ID 39).

Analysing data for aspects related to the potential of the mobile app to implement *Investigation* and *Explain* phases, and to promote multiple ways of *Expression* of scientific competences and interaction with scientific concepts/topics, 39 references were registered in teachers' answers. The references emphasized aspects related to the potential of the mobile app to help the students and/or the teachers:

- to manipulate scientific concepts, variables and/or phenomena with accuracy (e.g., "the mobile app provides accuracy and control of the variables"–ID 143);
- to view, demonstrate, materialize, simulate and/or experiment with scientific phenomena (e.g., "phenomena visualization"–ID 105; "to simulate schemes"–ID 33);
- to compare scientific data and/or phenomena (e.g., "to compare and experiment several phenomena"–ID 23);
- to mobilize scientific knowledge and skills (e.g., "allows to articulate concepts and procedures easily, facilitating knowledge systematization and application"–ID 212);
- to learn in an active way (e.g., "it is via experimenting that one learns"–ID 213).

For the aspects related to the potential of the mobile app to implement *Conclusion* and *Elaborate* phases, and to promote multiple ways of *Expression* of scientific competences, 20 references were registered in teachers' answers. The references emphasized aspects related to the potential of the mobile app to help the students:

- to apply scientific knowledge (e.g., "to apply knowledge"–ID 29);
- to consolidate and deepen scientific knowledge (e.g., "deepen their knowledge"–ID 113);
- to proceed towards new learning paths (e.g., "prepares the student for future learning"–ID 147).

Analysing data for aspects related to the potential of the mobile app to implement *Discussion* and *Evaluate* phases, and to promote multiple ways of *Engagement* with scientific concepts/topics, six references were registered in teachers' answers. The references emphasized aspects related to the potential of the mobile app to help the students:

- to deepen scientific concepts/topics understanding (e.g., "deepen complex scientific topics understanding–ID 108);
- to discuss/compare ideas/evidence/results (e.g., "compare (. . .) several situations"–ID 23);
- to reflect about topics/problems/challenges (e.g., "promotes a better understanding, and prepares the students for (. . .) curiosities that may emerge during the research"–ID 147);
- to evaluate their scientific knowledge development (e.g., "(the mobile app) would allow to (. . .) evaluate the knowledge"–ID 57).

3.4. Expected Adequacy of the Proposed Learning Approach to Promote Scientific Competences Development

Regarding the *Scientific Competences* category, data analysis demonstrated that most of the teachers consider that the use of a mobile app integrating correlated digital educational resources could promote *students' Scientific Knowledge* development (47 references registered). The references emphasized aspects related to the potential of the mobile app to promote:

- an organized, comprehensive, interdisciplinary and "hands-on" learning (e.g., "easy articulation of the concepts and the procedures, so that knowledge can easily be systematized and applied in practice"–ID 212);
- concepts/topics understanding (e.g., "to understand everyday life situations and phenomena"–ID 192);
- scientific knowledge deepening (e.g., "students have the opportunity to deepen their knowledge"–ID 113).

For aspects related to the potential of the mobile app to promote students' *Scientific Skills* development, 16 references were registered in teachers' answers. The references emphasized aspects related to the potential of the mobile app to promote:

- idea confrontation, observation analysis and/or discussion and knowledge application (e.g., "encourage new knowledge application"–ID 102);
- the definition and/or operationalization of scientific strategies/experiments (e.g., "to change the experiment variables"–ID 15).

Analysing data for the aspects related to the potential of the mobile app to promote students' *Scientific Attitudes* development, 40 references were registered in teachers' answers. The references emphasized aspects related to the potential of the mobile app to enhance students':

- curiosity, questioning and digging for more information (e.g., "a way to promote students' interest, developing an attitude of appreciation for science"–ID 170);
- involvement and maintaining motivation in learning process (e.g., "appealing to students and promotes their involvement in learning"–ID 11);
- critical reflection, sympathy, and respect for others, for the environment and for objects (e.g., "students will have a better perception of reality"–ID 35).

4. Discussion

Data analysis allowed inference about the expected adequacy of the proposed learning approach and its potential to promote a comprehensive and practical approach in Science Education, by allowing exploration of correlated digital educational resources, namely animations, games, simulations, quizzes and information areas. Furthermore, the teachers' answers also allowed inferences about the expected adequacy of the proposed learning approach to promote the student's scientific knowledge, skills and attitudes development.

First, the study demonstrated that most of the teachers adopting technology in their Science lessons used mainly animations (68.6%) and games (55.9%) (see Figure 2). The fact that only 38.1% of the teachers selected simulations from the options available in Q5 could be an indicator of the low availability of this typology in the Portuguese language (develop and/or adapted), as well as the low availability of simulations for primary school grades at the time of data gathering [78,79]. Since quizzes are a game typology, in Q5 and Q6 this typology was considered as a game option [72,80–83]. Regarding information areas, since they are not very common, they were not presented in the questionnaire. In this regard, it is important to refer to the fact that, within the Preliminary research, between 1 September 2015 and 18 September 2017 a survey was performed a survey related to the state of the art of mobile apps for Science Education, among others, (i) for primary-school students; (ii) developed by Portuguese stakeholders; (iii) available in Portuguese language; (iv) including (correlated) digital educational resources such as animations, games, simulations, quizzes, and information areas. The survey found nine mobile apps with those features, four from those from the same collection/stakeholder providing information areas. Another piece of useful evidence is the fact that, despite all the digital educational resources that *House of Sciences* provides, information areas are not available. This means that the study sample was not familiar with this type of digital educational resource. Instead, it was familiar with animations, simulations, videos, interactive presentations, games, interactive whiteboard resources, documents and activity exploration guides.

Regarding the use of digital educational resources in Science lessons, the study also demonstrated that most of the teachers used animations and games to introduce and apply scientific concepts/topics, respectively (see Figure 3). When matching teacher conceptions with the leaning approach proposal, although most of the teachers used simulations to explore and to deepen concepts/topics in their Science lessons, the verified frequency of usage was below 50% of the total sample (see Table 4). Thus, games typology was considered as a means to explore scientific concepts/topics, as proposed in the designed learning approach, and quizzes and information areas to deepen scientific concepts/topics. It is also important to mention that, at the time of data gathering, most of the available simulations in the Portuguese language and for primary school grades were similar to games [78,79]. In this regard, by choosing to maintain the proposed learning approach, the mobile app, simultaneously, allows diversification of the typology of digital educational resources available, and allows the students to use the most appropriate resources for each one of the possibilities proposed: to introduce, explore, apply, and deepen scientific concepts/topics.

Whether using technology in their Science lessons or not, data analysis demonstrated that most of the teachers expressed that they privileged a mobile app integrating correlated digital educational resources (i) to promote the students' orientation and engagement in the learning process, and (ii) to (re)present scientific information (see Section 3.3). Data analysis also demonstrated that most of the teachers privileged the use of a mobile app like the proposed one to promote students' scientific knowledge and attitudes development (see Section 3.4). Since references to all the defined categories and subcategories were found, data analysis predicted the expected adequacy of the proposed learning approach regarding the following: (i) integration of correlated digital educational resources in the mobile app; (ii) adoption of the UDL principles; and (iii) the simultaneous adoption of the IBSE and 5E theoretical frameworks from two related points of view: the teachers' role in the learning process simulated by the mobile app (IBSE) [28,84] and the students' learning process when interacting with the mobile app (5E) [30,62]; providing a comprehensive and practical Science Education approach and facilitating students' scientific competences development and self-regulated learning. In this regard, the proposed learning approach revealed itself to be adequate in providing a comprehensive and practical Science Education learning tool, and enhancing students' scientific competences development and self-regulated learning [2,58–60].

Finally, by crossing the theorized aspects with data collected, the expected adequacy of the proposed learning approach according to teachers' conceptions could be deduced. Therefore, the participatory and user-centred design approach allowed to confront and ground the literature-based rationale of the proposed learning approach. Data analysis and its impact detailed in the study aimed to share the foundations of the proposal with other researchers and enhance the importance of the design and (preliminary) validation of technological educational solutions among future end-users. Furthermore, the proposed learning approach and the adopted method to design and demonstrate its potential could represent a contribution to the development of innovative learning approaches in (Science) Education, aiming at students' engagement and helping them to deepen, understand and develop (new) competences.

The study presented minor limitations. Besides the limitation mentioned in Section 2.2 related to the fact that from the 230 answers to the questionnaire, 78 were incomplete and 34 were not properly saved in the *University of Aveiro Questionnaires* platform due a system failure, the authors had to wait 23 days for formal consent to adapt to Portuguese language items of one of the instruments. Three e-mails had to be sent to reinforce the request. This constraint resulted in a one-month delay in the following processes: (i) translation of the adopted items; (ii) backtranslation of the adopted items; (iii) questionnaire pilot version design; (iv) questionnaire pilot version validation; and (v) questionnaire pilot version implementation in the *University of Aveiro Questionnaires* platform.

The authors support the idea that the learning approach proposal can contribute to (research in) Science Education by proposing the combination of the UDL principles, the IBSE and the 5E. From data analysis, the authors also support the idea that the proposed approach can (a) facilitate scientific concepts/topics/phenomena approaches; (b) represent an opportunity for students to explore scientific contents/topics in an organised, comprehensive, and practical approach; (c) promote students' scientific competences development (scientific knowledge, skills and attitudes); and (d) facilitate students' self-regulated learning. Since the proposed learning approach is quite comprehensive, it could be expanded to other educational software. With this paper, the authors also aim to contribute to Education Science by providing a validated questionnaire aimed at surveying primary-school teachers' conceptions about their knowledge and educational practices in Science Education using digital educational resources.

With wider study, among other aspects, the authors aim at to contribute to Education Science by (a) providing a participatory framework proposal for guiding researchers through an educational mobile app development [24], representing an opportunity for researchers in Education and Multimedia (in Education) to develop educational software based not only on the state-of-the-art, literature in the area and their own rationales, but also on the users' perceptions, ideas and needs, and on experts' validation; and (b) deepening knowledge in the area of EDM and proposing a relational structure [28] and a conceptual EDM framework developed for the mobile app, both extendable to other Science Education software, representing a new perspective on technology enhanced learning and on how to extract valuable educational data to guide students' scientific competences development and self-regulation of learning, as well as to help teachers and researchers to understand and support students in those processes.

Future work is related to the mobile app development, testing and implementation in a school setting, to investigate the adequacy of the learning approach, namely the actual practicality and the actual effectiveness. By validating practicality, the authors intend to understand if the mobile app is usable in the settings for which it has been designed and developed. Finally, by validating its actual effectiveness, the authors intend to investigate mobile app usage and relevance according to the desired outcomes: students' scientific development and self-regulated learning.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. All the participants have been informed about the aim of this study and of the use of data collected.

Data Availability Statement: The anonymized data is available open access on *figshare*® [29]. This study meets the necessary ethical requirements and does not include activities or results that pose safety problems for the participants. All data were treated confidentially, and the participants were treated anonymously in the study.

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Appendix A

Table A1. Deductive System of Categories: potential and future usage of the mobile app regarding the expected adequacy of the proposed learning approach.

Categories	Subcategories	Description
User Experience Potential/added value to approach scientific concepts/topics/phenomena [49,58,61,62]	Desirable	The visual aesthetics and the presentation of scientific concepts/topics/phenomena became more attractive using the mobile app
	Usable	Scientific concepts/topics/phenomena are easily explored/manipulated using the mobile app
	Useful	Scientific concepts/topics/phenomena are easily organized/approached using the mobile app
	Valuable: Orientation, Engage, and Representation	Orientation (IBSE): the mobile app aims to stimulate students' curiosity about a particular concept/topic; and to promote students' self-evaluation about previous knowledge. Engage (5E): the mobile app aims to draw students' attention/interest; to involve the students in a personal way; and to stimulate the students to predict, relate and evaluate their previous knowledge. Representation (UDL): the mobile app promotes multiple ways of scientific information representation, enhancing the introduction and presentation of scientific concepts/topics (e.g., animations).
	Valuable: Conceptualization, Explore, and Engagement	Conceptualization (IBSE): the mobile app aims to lead the students to form assumptions; and to test students' assumptions according to the established dynamics through inquiring. Explore (5E): the mobile app aims to promote students' actively learning; to stimulate the students to analyse information, observe and compare phenomena, variables and concepts; to help the students to identify requirements and variables that influence outcomes; to help the students to interpret results; and to stimulate the students to draw and confront conclusions. Engagement (UDL): the mobile app promotes multiple ways of engagement, expression and interaction, enhancing the exploration of scientific concepts/topics (e.g., games).
	Valuable: Investigation, Explain, and Expression	Investigation (IBSE): the mobile app aims to lead the students to form assumptions, to plan processes, to test assumptions, and to collect, analyse and interpret data. Explain (5E): the mobile app aims to stimulate students' reflection about how they structure their conceptual framework and the designed research path; to help the students to draw conclusions and structure their knowledge; to lead the students to confront their initial ideas with the results of the experimental activity; to help the students to establish a theoretical framework about their meaning; and to help the students to establish relationships between their choices and the initial research question. Expression (UDL): the mobile app promotes multiple ways of expression and interaction with the information, enhancing the application of scientific knowledge and skills (e.g., simulations).
	Valuable: Conclusion, Elaborate, Expression and Representation	Conclusion (IBSE): the mobile app aims to lead the students to draw conclusions; and to help the students to reflect about how they construct their knowledge. Elaborate (5E): the mobile app aims to promote students' knowledge mobilization; to help the students to discover and understand the implications of the phenomena explored; to help students to establish relationships with other concepts/topics; to lead the students to deepen/expand their knowledge; and to help the students to clarify doubts. Expression (UDL): the mobile app promotes multiple ways of expression, enhancing the deepening of scientific knowledge and skills (e.g., quizzes). Representation (UDL): the mobile app promotes multiple ways of scientific information representation, enhancing the deepening of scientific knowledge and skills, and helping the students to proceed in their learning path (e.g., information areas).
	Valuable: Discussion, Evaluate, and Engagement	Discussion (IBSE): the mobile app aims to reinforce/deepen students' knowledge; and to help the students to self-regulate their learning (e.g., what content to explore). Evaluate (5E): the mobile app aims to lead the students to evaluate their understanding of a scientific concept/topic; to lead the students to apply their (new) knowledge; to lead the students to deepen their conceptual framework or advance towards new research paths; to lead the students to constantly and continuously be aware about how much they have learned and how their conceptual framework evolved; to help the students to a greater understanding of the scientific competences developed; to help the students to find ways of self-correction and readjustment. Engagement (UDL): the mobile app promotes multiple ways of engagement, enhancing the students' interest and persistence in learning process (e.g., formative feedback, recommendations).

Table A1. *Cont.*

Categories	Subcategories	Description
Scientific Competences Potential/added value to promote scientific competences development [1,67–72].	Scientific knowledge	Potential to promote scientific knowledge development: the app mobile aims to lead the students to explore/contact with concepts; terminologies; concept/topic-specific details; classes, categories, principles, systems and scientific phenomena; define and/or interpret experimental procedures; deepen scientific concepts and/or specific details related to the concept/topic addressed; verify the domain of scientific concepts; deepen scientific phenomena.
	Scientific skills	Potential to promote scientific skills development: the mobile app aims to lead the students to identify or formulate criteria to draw possible answers; decide (by attempting) about the best action/procedure; observe, analyse and/or interpret scientific systems and/or phenomenon variations; interpret statements and answer questions; analyse statements and (ir)relevant information; analyse and resume ideas, statements, arguments; perform strategies and research plans; identify necessary assumptions to understand scientific concepts/topics.
	Scientific attitudes	Potential to promote scientific attitudes development: the mobile app aims to lead the students to access to more information to solve a problem; find alternatives to validate the set criteria; mobilize knowledge to analyse statements, relevant information, and answer correctly; find ways to be well informed about scientific concepts/topics; and to promote students' reflection on knowledge construction; self-awareness of their learning; and self-evaluation about previous knowledge.

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