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Review

Virtual Galleries as Learning Scaffolds for Promoting Problem-Based Learning

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Abstract: Extensive research into the effectiveness of problem-based learning (PBL) in primary and secondary education has been carried out over the past few years. PBL is an appealing, promising, but also challenging educational approach for both students and teachers. To overcome challenges, one of the most popular proposed strategies is to build learning scaffolds that gradually help students to effectively resolve the emerging sub-problems and tasks. Moreover, the massive impact of technology on students' lives, and the transition from in-person to distance teaching (especially during the COVID-19 pandemic) highlights the necessity of using virtual worlds and digital tools to facilitate and amplify collaboration and communication, both synchronously and asynchronously. This paper introduces the virtual galleries method as a scaffold for applying PBL approaches in both physical and distance learning environments, within the field of STEM education. Virtual galleries are perceived as a practice that motivates learners to collaborate, express their ideas on solving a problem, and present them as interactive and immersive experiences, while allowing others (peer-learners and educators) to evaluate the produced solutions. In this context, it is argued that virtual galleries can facilitate PBL by serving as a conceptual framework for scaffolding the learning process, thus enabling the acquisition of new PBL-driven skills.

Keywords: virtual galleries; learning scaffold; problem-solving; collaborative learning; distance learning; STEM education

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1. Introduction

During the past few years, several educational attempts and a lot of research has been conducted to effectively adopt PBL in primary and secondary education [1–4]. Even though PBL is a rather appealing and quite promising approach in education [1,5,6], researchers and educators [1,5,7–9] stress that the entire process is quite challenging, not only for students (especially the younger ones) but also for teachers, since both of them are unfamiliar with the new roles that they have to adopt (i.e., constructing knowledge and progressively becoming self-driven learners for the former, and acting as facilitators for the latter). To tackle challenges and to avoid pitfalls and misconceptions, one popular strategy is to build learning scaffolds that progressively aid students in efficiently addressing the emerging sub-problems and tasks, without discouragement and loss of interest [1,5]. Therefore, this paper begins by reviewing several theories and research that have been conducted in the field of PBL in recent years. Section 2.1 aims to briefly explain what PBL is, underline parameters that characterize this concept, and highlight several suggested and applied methods and strategies toward the successful implementation of this approach in education.

Given the massive impact that technology has on students' lives, as well as the shift from face-to-face to e-learning teaching due to the COVID-19 pandemic, other suggested strategies revolve around the use of virtual worlds and digital tools that can efficiently support and enhance collaboration and communication, in synchronous and asynchronous ways [10–13]. In this regard, research on the type of learning environments and tools that can sustain and promote PBL is performed (and presented in Section 2.2), with a particular emphasis on the culture of virtual and distance learning, which was significantly boosted in recent years due to the COVID-19 pandemic. The findings of this brief research, combined with PBL theories, reveal a gap in the current literature. Despite the availability of various tools and services that can foster and boost PBL practices in both physical and distance learning environments, there is a lack of a conceptual framework to scaffold this learning process using a PBL approach.

In this context, the virtual gallery concept is introduced and suggested as a scaffold for promoting and implementing PBL approaches in both physical and distance learning environments. Section 3 begins with a brief definition of the virtual gallery approach and cites previous examples of its application. In this paper, a virtual gallery is not solely a digital space for exhibiting several items. It is perceived as a wider method that inspires learners to collaborate using physical and digital tools both individually and as a team, to effectively illustrate, organize, and present their ideas as an interactive 3D spatial narrative. Through the cited examples, several findings and hypotheses are highlighted regarding the utility of the virtual gallery approach in STEM education. Subsequently, Section 3.2 further explores this argument by outlining a feasible implementation of this approach within the framework of PBL. The stages involved in this process are presented through a diagram illustrating the relationship between setting up a virtual gallery and ways of addressing and proposing a possible solution to a given problem, leading to recommendations on how virtual galleries can be used as a scaffold to promote PBL. It is suggested that the virtual gallery approach can aid in a gradual and effective familiarization of students with the PBL concept, while facilitating the acquisition of new PBL-driven skills. Furthermore, it is argued that this methodology has the potential to introduce innovative approaches that will inspire and encourage learners to perceive learning as an interactive and collaborative journey of exploration, inquiry, creation, and sharing.

2. Researching PBL Theories and Types of Learning Environments That Can Sustain PBL

2.1. Review of PBL Approaches

PBL was initially proposed and applied in higher education (and particularly in medical schools in North America) as a more effective and alternative—in respect to traditional—learning approach, while over the last 25 years there have been multiple efforts to introduce this method to primary and secondary education [1–4]. Some of the aims of PBL are to help students to understand and investigate a problem, to discover solutions to emergent demands, to work collaboratively and to communicate their ideas during this process, to evaluate the results (through self and peer assessment), and, ultimately, to increase their critical and high-order thinking skills [1,5] (which are considered powerful and crucial cognitive and meta-cognitive skills, also acknowledged as some of the so-called 21st century skills).

Ref. [5] defines PBL as an "instructional approach," revolving around learners who act as researchers, by trying to combine theory and practice and by applying the gained knowledge and skills to find a possible solution to a defined and real-world problem. The problem that is used in PBL does not have a single solution [6]. Therefore, more than one interpretation and approach can meet the demands of the initial question, while the field of research is not limited, meaning that more than one discipline or subject might need to be studied and explored. Learners who are engaged in PBL do not necessarily have prior or/and sufficient knowledge of the subject they are investigating, nor have they been exposed to a similar example [2], so they need to delve into different fields—both individually and as a team—to search for information and generate a solution. Due to these facts, it is argued that students are more motivated since they are responsible not only for discovering a reasonable solution for a rather multifaceted problem, but also for identifying the different aspects of the problem and setting the right parameters to resolve it [5]. These actions are among the four stages that [14] highlight as typical in a PBL case: the need to clarify the problem, to identify the underlying needs to properly address this problem, to study and learn at an individual level to acquire new skills and knowledge, and then to apply the skills and knowledge to solve the initial problem. At its core, PBL is a self-directed learning process, but with the need for constant evaluation of and reflection on the emerging ideas, both at the individual and team level. The ultimate goal is a viable solution that can be meaningfully applied in the real world.

Even though PBL is an appealing concept, it is not a simple or/and straightforward learning method. In fact, it is quite challenging for both teachers and students [1,5,7]. Contrary to traditional learning approaches, in PBL learners are responsible for directing and regulating the learning process as well as monitoring "their own understanding" [8], while teachers have to act as facilitators, by discreetly assisting them, mostly through questions that will help learners focus on significant aspects of the problem [5,9]. This process is difficult since both students and teachers are unfamiliar with these new roles. The former may not have developed to a high level the cognitive skills (e.g., critical thinking, problem solving) necessary to deal effectively with an ill-structured problem. The latter should be properly trained to become facilitators and to assist students in operating at a metacognitive level (i.e., perceiving and critically reflecting on the acquired knowledge) [1,8].

To overcome these difficulties and successfully implement PBL in secondary education, while avoiding pitfalls and misconceptions, a range of strategies must be adopted and employed. Toward this end, one of the essential parameters that several researchers highlight is collaboration and interaction between learners, especially those who are working on the same group [1,5,14]. Teachers/Facilitators need to inspire students to effectively work as teams by suggesting methods such as setting goals and internal deadlines, discussing and reflecting on others' ideas, as well as allocating roles. Many researchers are also putting emphasis on the significance of building learning scaffolds that will assist students to progressively resolve the emerging tasks, without disappointment and loss of interest [1,5]. For instance, ref. [1] proposed the concept of "postholes": a number of shorter problems that can be used as examples for smoothly introducing students to the PBL method. Setting checkpoints or having some kind of progress recording (such as a goal chart or a diary) is another strategy for keeping students engaged. This strategy ensures that the steps taken to solve the problem are consistent with its content. This approach will enhance students' awareness of the correlation between the produced outcomes and the initial inquiry, consequently leading to a better understanding of the acquired knowledge [5]. Ultimately, teachers should keep in mind that the designed tasks of PBL, as well as the immanent demands, should be authentic, meaning relevant to real-world cases [15], and compatible with learners' cognitive skills [8] (p. 139). In this sense, it is also proposed that some discussion and negotiation between learners and facilitators should take place before establishing the final task. Moreover, it is argued that if learners are exposed to a problem that activates prior knowledge, then the entire process is more engaging for learners [7], and the new knowledge that is formed and gained is more meaningful [2].

In many cases, the educators blend PBL with other learner-centered strategies such as project-, case-, and inquiry-based learning [3,5], which are also oriented toward self-directed learning and promotion of skills such as collaboration, communication, critical thinking, and problem-solving, but—in comparison to PBL—their final outcomes are more concrete. Due to these similarities, these strategies are sometimes used by the facilitators as scaffolds for PBL. Project-based learning, in particular, is considered by several researchers as almost identical to a PBL approach, with rather minor differences [3,6,15]. One of them is that, unlike PBL, in project-based learning, the facilitators may choose to give direct instructions to the learners to help them find a viable solution [15]. Another one is that it relies on the final outcome, which in PBL is defined as a solution, but in project-based learning the terms "product" and "artifact" are used [3]. Other than that, both methods are characterized by collaborative learning and knowledge construction resulting from several interrelated stages, including brainstorming, researching, planning, testing, evaluating, and reflecting on the results [16]. Focusing on the learning outcomes, and particularly on improving students' engagement and critical thinking, ref. [17] suggest a hybrid model, called "Constellation 3: project-led problem-based learning," that combines both approaches by using the project as a container and a space that fosters PBL practices, toward knowledge acquisition. The notion of "constellations" reflects the existence of a variety of PBL approaches, constituting patterns that are not "just within the types of PBL" but extended to other fields of pedagogical practice [9] (p. 4). In this sense, ref. [9] suggests that it would probably be more fruitful and meaningful "to explore components and concepts that together can begin to build pedagogies for PBL," leading to the production of new ideas, the imagination of new futures, and the blurring of boundaries found in particular practices.

Implementing such a practice could potentially aid in the development of PBL learning techniques that are not merely trying to trace over or rely on some sort of "gold standard PBL" [9] (p. 3), which may be misleading regarding the objectives of a given problem, but that instead pave the way for innovative methods that emphasize motivating and encouraging students to perceive learning as a dynamic process of exploring, questioning, creating, sharing, and, ultimately, "as an opportunity to challenge, change and transform the world" [9] (p. 7).

2.2. Learning Environments and PBL

The selection of the strategies and pedagogies (that can promote and scaffold PBL) is also related to, and affected by, the type and the structure of the environment where the learning process occurs [9]. According to socio-constructivist and cultural perspectives, learning is inextricably bound to the interplay between learners and the environment fostering learning practices [10]. Therefore, and in order to meaningfully promote learning, it is crucial for educators/facilitators to select an environment that effectively serves the objectives of the chosen educational methodology, as well as the tasks to be carried out [10]. As mentioned above, for PBL to be successful, it is essential to have an environment that encourages collaboration and interaction not only between learners, but also between learners and facilitators. For instance, ref. [1] (p. 43) argued that learning environments fostering PBL need to promote collaboration since it permits students "to draw on each other's perspectives and talents in order to more effectively devise solutions for the problem(s) at hand." Therefore, it is equally important that the learning environment gives opportunities to students for expressing and practicing different ideas, as well as for sharing experiences.

According to [18], an "effective learning environment" is defined as an educational setting (in physical or virtual mode) that fosters discussion and interaction among learners and facilitators in such ways that leads to the construction of knowledge and problem solving through collaborative learning. However, concerning in-person teaching, the time in the classroom is often limited, and there is not enough for effective and fruitful collaboration between students [19]. Toward this end, new technologies and the available educational digital tools can play a significant role [15]. By providing means that encourage discussion, argumentation and negotiation, brainstorming, planning, creation, and experimentation, in synchronous, asynchronous, and remote modes, these technologies can support distant interaction and productive collaboration, while extending learning practices beyond the time in class. The culture of distance learning through virtual classroom settings was significantly boosted in the last few years due to the COVID-19 pandemic and the emerging restrictions.

During the COVID-19 pandemic, there was a massive shift toward virtual and digital environments, as substitutes for in-person communication and interaction, prompting the exploration of alternative approaches (including PBL) through the lens of virtual tools and environments. Consequently, the educators sought tools to counterbalance the "loss of physical presence" and create more engaging online learning [11]. However, collaborative learning in virtual spaces is considered an even more demanding process since learners are exposed to "new ways of communication and collaboration" [10]. Moreover, the shift to new technologies does not imply a better or more effective learning approach and, consequently, a better educational quality unless new forms of meaningful and interactive learning are supported and encouraged [12]. As [13] pointed out a few years ago, the use of virtual environments for educational purposes can be considered successful if the promoted learning experience feels real to learners and engages them in the learning process by creating a sense of presence in a cognitive and emotional way.

In this context, it has been argued by [11] that one obvious option for implementing PBL online is to use virtual tools that do not support the linear and fixed narrative that typically characterizes traditional and paper-based PBL, but instead emphasize immersion and learner engagement by challenging them to collaborate online to solve different tasks. Regarding online collaboration, ref. [10] believes that in order to meaningfully support learning processes, collaborative virtual environments should provide three crucial affordances, namely (1) technological, (2) social, and (3) educational affordances, which concern, respectively, the technological means and tools, the properties boosting social interaction, and the learning behaviors that are shaped. But as [10] argues, "it is unlikely that a single platform can meet the interaction needs of this joint activity." Therefore, he highlights several tools that can promote these qualities, such as forums and social networks that boost the sense of community and presence as well as dimensions related to cognition, tools that promote collaborative authoring and annotation, tools working as digital repositories for information (blogs), as well as e-portfolios, functioning as personal diaries where personal achievements in the form of artifacts and self-reflecting writing items are collected. For e-portfolios in particular, ref. [10] argues that they have great "potential for metacognitive activities such as planning and organizing, monitoring, and regulating collaborative learning," especially when they "are considered as collaborative systems, providing opportunities for assessment, self-assessment, and co-evaluation."

The aforementioned tools can support various aspects of teaching and learning, and they appear to include practices cited by [9] for boosting PBL, such as providing communication channels, fostering team building, and promoting experimentation and co-production, while enabling students to choose means that match their personal interests and abilities. Nevertheless, they seem to lack one significant parameter. They do not suggest or establish a concrete concept for the learning process to occur. It is argued that the concept of virtual galleries can offer this framework, bringing forward strategies of collaboration, creation, interaction, and sharing between learners.

3. The Virtual Galleries Concept as a Scaffold for Promoting PBL

3.1. Introducing the Concept of Virtual Galleries

In general, a virtual gallery is defined as any digital space that tries to promote some kind of artwork through a more or less interactive environment. The level of interactivity within the environment is closely linked to the approach and design of the virtual gallery (i.e., whether as a webpage or a 3D model) and the navigation methods deployed to engage users/visitors. However, in the context of this paper, virtual galleries are more than just digital spaces for displaying artwork; they are alternative narrative mechanisms and flexible spatial configurations in which the students can organize and reflect their ideas and thoughts, in multimodal formats (i.e., as images, texts, videos, etc.) and in meaningful and interactive ways. Additionally, virtual galleries are perceived as a means for building communities (around specific topics/themes), enhancing communication (between community members), and facilitating the exchange of information and experiences. Moreover, given that virtual environments are not trying to substitute reality but, rather, enhance it with new potentialities, a virtual gallery is ultimately considered a tool for amplifying and expanding physical learning experiences. To exemplify the concept and application of virtual galleries for educational purposes, two use cases will be briefly presented in the following subsections.

3.1.1. Use Case 1: The BeReady Project

The idea of using a virtual gallery as a pedagogical method came up after research on available tools that can support project-based methods for teaching online STEM-related courses. This research was performed in the context of the BeReady project [20], an Erasmus+ project revolving around the continuation of teaching STEM subjects during the COVID-19 pandemic. In this project, a handbook [21] was produced, gathering several digital/virtual tools with powerful features that can enable learners to collaborate online, as well as create and illustrate their ideas in multimodal ways, while fostering actions such as ideation, communication, planning, and sharing.

These tools were combined in light of several learning scenarios, including the production of 3D virtual experiences, in the form of virtual galleries. Considering the space of a virtual gallery as an infrastructure for better organizing and presenting content, thus generating immersive narratives enhanced with spatial and embodied aspects, but also as a space that can support collaboration, creativity, interaction, and sharing between learners, it was argued that such an approach can be a rather powerful method for teaching STEM subjects online [22,23]. This argument was reinforced after implementing the learning scenario of virtual galleries with teachers from secondary schools during four webinars [22].

The participant teachers (20 in total) formed four teams and were instructed to select a topic of personal interest (e.g., science in ancient Greece, aspects of AI, etc.) and present it through a virtual gallery, using the Artsteps application [24], a free-licensed tool that permits the creation of virtual galleries from scratch. The teachers collaborated online both individually and as teams to gather information, produce artifacts with various tools proposed in the handbook, strategize the embedding of information into the virtual gallery, place the artifacts, plan a guided tour, and exhibit the outcomes to others [22]. Although they used multiple digital services and tools to collaborate and produce the content for their gallery (such as [25–27], etc.), the virtual gallery served as the pivotal point around which the entire learning process was coordinated. At the end of the webinars, the teachers were asked to provide feedback on their experience by completing an online questionnaire.

According to their feedback, the teachers identified the process as a good example of how a STEM project can be effectively carried out online [23]. They appreciated the balance between theory and practice and the initiation of dialogue on a specific topic through the virtual gallery concept. They also valued the autonomy to choose a topic relevant to their personal interests and to gain expertise in new tools that promote interdisciplinarity. Some teachers implemented the acquired knowledge in their classes. During webinar 4 [22], a teacher reported that a student at their school used the concept of virtual galleries to deliver a presentation on the subject of optics in physics. This immediate implementation provides evidence that the concept of virtual galleries is both interesting and pertinent to the needs of the school community. One weakness identified was the Artsteps tool's inability to facilitate simultaneous collaboration within the same environment. Even though team members can access the 3D model of the virtual gallery by using the same registration code, they cannot observe modifications made by one user instantaneously. To tackle this problem, the teachers worked on the 3D model in a rotational manner. They also scheduled online meetings to discuss the achieved outcomes and the next steps toward finalizing their virtual gallery.

3.1.2. Use Case 2: The CULPEER Digital Project

The virtual gallery method was also employed during the CULPEER Digital project [28,29]. In this project, a group of students (aged 18 years old) worked together using the Artsteps application to create their own virtual gallery, thus promoting intercultural exchange and cultural peer-to-peer learning in a digital format. The participating students were encouraged to identify a contemporary cultural aspect of Greece with links to the daily lives of Greek people. The students were inspired by their daily use of the Athens metro and proposed promoting the presence of art within Greek public transportation, since they noticed that the majority of the metro stations are embellished with artwork, such as painting, sculptures, and installations, created by Greek modern artists. Therefore, initially they chose to gather data on the showcased artwork situated in different metro stations in a shared Google document. They uploaded representative images of the artwork, and for each one, they recorded the title and the artist's name, accompanied by a brief description. Then, they used the Artsteps application to produce an interactive virtual gallery exhibiting the gathered data, allowing engagement with groups of learners from around the world and making all these objects of Greek modern culture visible to a wider audience. During this project, it was highlighted that the students enjoyed the entire process. They encountered no difficulty in using a 3D modeling environment such as Artsteps, and they felt creative and enthusiastic about producing their own content. To overcome the limitation of Artsteps regarding online collaboration, the students were encouraged to have a physical meeting to work jointly on the 3D model of the virtual gallery.

3.2. Toward a New Approach for Facilitating PBL

Although the number of participants was limited, the aforementioned experiences led to some valuable insights and hypotheses. It was observed that a virtual gallery can serve as a digital space that consolidates a variety of items and ideas, united by a common theme, thus generating numerous and immersive narratives. It was also noted that the tools and methods used to produce a virtual gallery can be easily implemented by both students and teachers, (with the former needing less time to become acquainted with the new digital skills). Furthermore, the whole procedure was perceived as a creative process that fosters collaborative learning. Based on these observations, and considering the theories of [9] regarding the integration of components and concepts from different pedagogical practices, it is suggested that virtual galleries have the potential to facilitate different learning approaches, including PBL, in both physical and distance learning environments. Moreover, it is argued that virtual galleries can function as a concrete concept for scaffolding collaborative learning and problem solving in light of PBL. In this respect, ref. [21] can be a valuable source for discovering tools that can facilitate PBL practices. The following paragraphs delve into the creation of a virtual gallery through the use of 3D modeling software such as Artsteps, along with certain tools included in [21]. The stages involved in this process are presented, together with recommendations on how virtual galleries can be used as a scaffold to promote PBL.

3.3. The Virtual Gallery Scaffold

Figure 1 contains a diagram that illustrates the relationship between the steps involved in setting up a virtual gallery (left sequence) and the process of addressing a problem and proposing a possible solution (right sequence), and how the former can serve as a scaffold for promoting the latter.

As shown in the left section of Figure 1, the process of developing a virtual gallery can be divided into five main steps. The first step is to determine the main topic. Then, to facilitate the process, the designer creates a preliminary 3D model of the virtual gallery to serve as a basic infrastructure and a starting point for the following steps. This 3D model is subject to change, according to the needs that arise after the production of the artifacts. The next step involves the generation, production, design, and selection of artifacts. The artifacts can be any item that reflects the central topic. An artifact can be perceived as an image, a text, a 3D object, a video, or/and an audible item. The creator can choose any means to produce their artifacts. Depending on her/his intended representation, s/he can employ any physical or digital medium that will help her/him to produce it. Therefore, the creator can use a wide range of tools, from sketch pads and notebooks to cameras, as well as from image-generating software to 3D modeling software. If more than one creator is involved in the process, they can allocate roles based on their individual skills and talents. After producing the artifacts, the designer/creator must consider the order in which they will be presented to another person/visitor, so as to reflect and spatialize the main theme in the most effective way. Consequently, this process will enable the creator to determine the placement order of the artifacts in the virtual gallery, creating a flow of information that will generate meaningful narratives, leading also to make some final decisions regarding the spatial configuration of the virtual gallery (i.e., the number of the rooms in the 3D model, how they are interconnected, etc.). Again, if there are multiple creators, they can discuss and reflect on others' creations to reach a unanimous agreement on how the artifacts will be arranged. Toward this end, the creator(s) can consider incorporating mechanisms that will allow visitors to become more immersed in the entire 3D spatial narrative and experience. Potential mechanisms include providing titles for each section or item, additional texts and directional signs, etc. After considering all these aspects, the artifacts are placed in the 3D space of the virtual gallery by the creator, who may also choose to design a guided tour for visitors to follow while present within the virtual gallery. Once the virtual gallery has been prepared, the creator may invite other individuals/visitors to navigate the space, interact with the artifacts, and provide feedback on their experience.

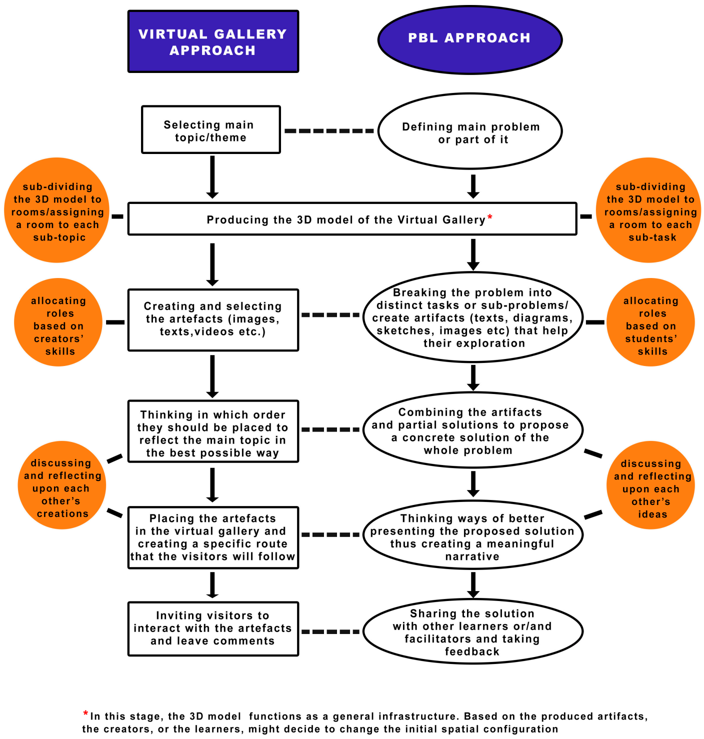

Figure 1. Diagram depicting the relationship between setting up a virtual gallery (**left sequence**) and addressing a problem and suggesting a feasible solution (**right sequence**).

It is argued that the implementation of the virtual gallery approach can act as a scaffold in PBL, leading students to become familiar with the method and to gradually learn to reach potential solutions to problems in STEM education. In this context, the central topic of the gallery will be the main problem (or part of it), and the artifacts will be all the possible approaches toward the solution. Breaking down a problem into distinct tasks or sub-problems and transforming ideas into tangible artifacts may assist learners in comprehending and addressing the initial inquiry, facilitating the identification of emergent demands and underpinning needs. For instance, consider that the initial problem is to "Design a sustainable water purification system": to supply a community with clean and safe drinking water (Figure 2). To address this problem, students should work as a team and consider various factors, such as the sources of contamination, the methods of purification, and the environmental impact, through the lens of different disciplines, including chemistry, engineering, and environmental science. This real-world issue can be deconstructed into sub-problems by encouraging each group member to select one of the aforementioned factors and to analyze it through a discipline that aligns with her/his interests. This allocation of roles can inspire students to use different methods of representation and allow them to choose techniques that correspond to their individual skills (such as creating diagrams, producing images, composing brief written pieces, etc.). This approach could help them in drawing on each other's talents and perspectives (by expressing their ideas in a more or less verbal way), leading to a better collaboration. Before starting their independent research, the teacher can advise the students to create a preliminary 3D model of their virtual gallery in order to give them inspiration for the design and presentation of their artifacts.

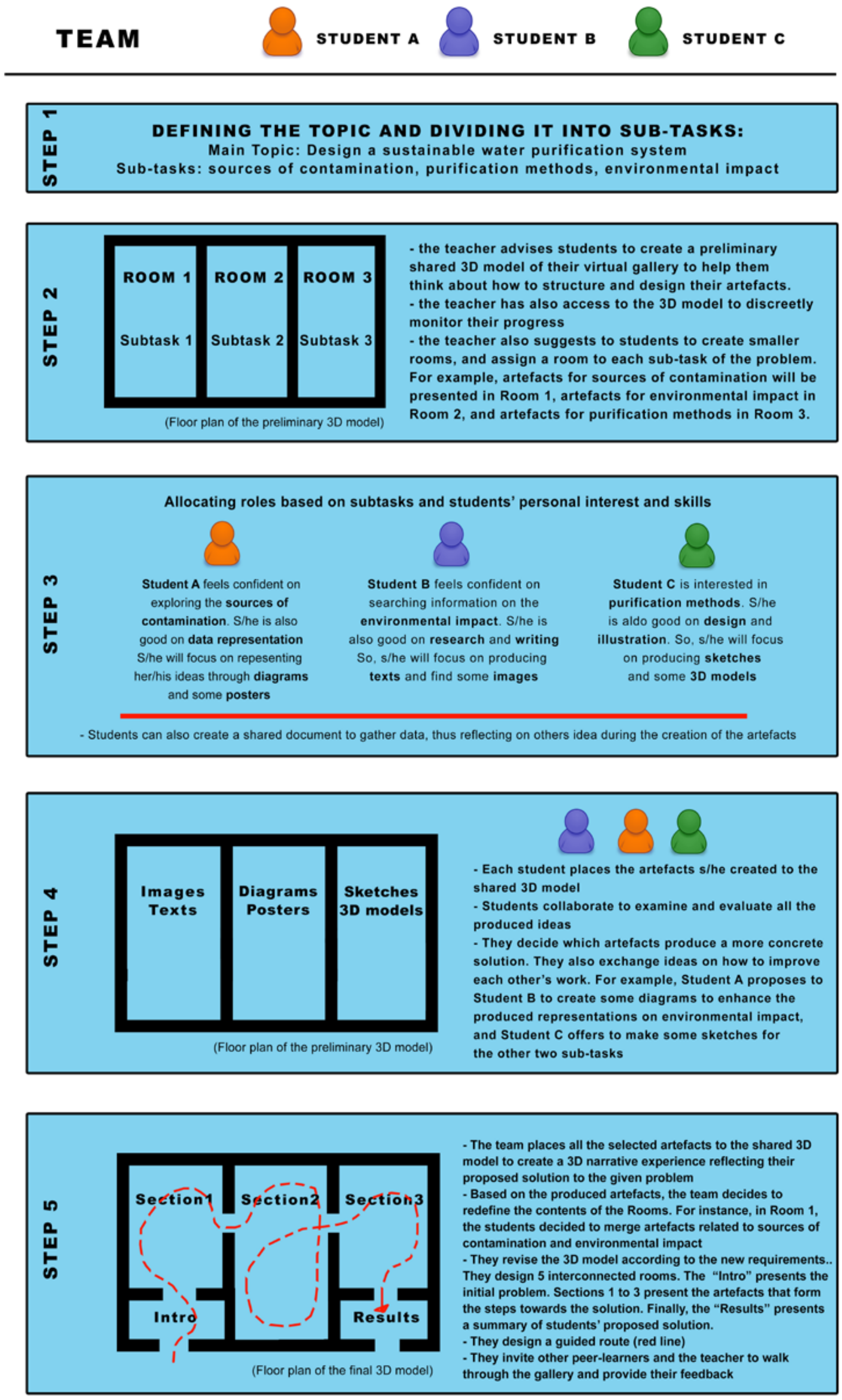

Figure 2. Image depicting the steps to address the problem of the "Designing a water purification system" scenario, by implementing the concept of virtual gallery.

To facilitate this process, the teachers can encourage learners to come up with a title that describes the artifact they are creating, which will help them approach the task. As the 3D space of the virtual gallery can be divided into smaller rooms, teachers can suggest students assign a room to each sub-task of the problem. This method could aid students in dividing problem solving into tasks more easily, as each one can select a specific gallery room to work in. For instance, in the "water purification system" scenario, each student could be assigned a room where they would present the results of their independent research. Additionally, this process (including role allocation) can be advantageous not only for learners but also for teachers as it offers them methods for checking the intermediate steps toward solving a problem and the coherence of the produced approaches with the initial inquiry. It also facilitates them to discreetly monitor the students' cognitive abilities and provide appropriate guidance for successfully developing PBL-relevant skills.

During the production of the artifacts, the learners should work both collaboratively and individually. After generating several possible approaches (in the form of artifacts), students can examine and evaluate their own and others' ideas, deciding which artifacts can be combined to produce a more concrete solution for the problem. With the aim of arranging their ideas in a spatial configuration and incorporating interactivity and navigation parameters, they are increasing their awareness of how to integrate all the proposed approaches, so as to generate a meaningful solution. The last step is to place all the selected artifacts in the virtual gallery, design a guided tour that fully reflects the proposed solution as a 3D narrative experience, and share the outcome with teachers (and other peer-learners) by inviting them to walk through the gallery, interact with the proposed approach, and provide their evaluation and feedback.

In summary, it is argued that the concept of the virtual gallery can serve as a scaffold for promoting PBL, particularly in secondary education. It is a concept that aids in dividing a specific problem into smaller tasks, enabling students to recognize emerging needs more effectively. It is also a method that supports collaboration and teamwork, and it allows the allocation of roles based on specific skills and talents. Furthermore, it is a strategy that tries to draw on prior knowledge and experience through means and tools that are familiar to students or that are easy to be taught (i.e., virtual environment, sketchpads, 3D modeling, etc.). By adding the spatial parameter to problem-solving, thus turning the entire process into a more tangible procedure that brings into play embodied aspects (i.e., locomotion/navigation and interactivity), it is postulated that students might feel more confident finding ways to materialize their ideas and experiment with different narrative mechanisms toward feasible solutions.

4. Discussion

This paper argues that the virtual galleries approach can serve as a learning scaffold for promoting PBL in physical and digital educational environments. A virtual gallery is perceived as a wider method that motivates learners to employ several physical and digital tools toward organizing, rendering, and presenting their ideas as spatial and interactive 3D narratives. Previous implementation of virtual galleries [20,22,23,28] as a method for teaching STEM subjects online suggested that it is a promising educational approach. This is because it encourages collaborative learning and creativity in an easily accessible and user-friendly environment for both teachers and students. These findings align with recommendations from researchers such as [9,17] who have proposed blurring the boundaries found in specific practices by exploring and combining components and concepts from various approaches to build pedagogies for PBL. It is also in line with suggested strategies [1,5] for constructing learning scaffolds in the form of short tasks to gradually introduce students to different steps of PBL. Consequently, it can be assumed that the approach of the virtual gallery may serve as a learning scaffold toward introducing PBL. This assumption is supported by the fact that the virtual gallery environment enables the subdivision of a problem into distinct tasks and the transformation of ideas into tangible artifacts, thus making easier for learners to comprehend a given problem and identify the immanent needs. It is also sustained by the fact that a virtual gallery promotes collaboration, interactivity, and the exchange of ideas among students, and it does that by encouraging the use of a variety of tools that match students' personal interests and abilities. Furthermore, both educators and learners can provide feedback by evaluating and commenting on the results. Therefore, this environment exhibits the three affordances outlined by [10], namely technological, social, and educational, and it does not rely on a single platform or service, which is in accordance with [10]'s assertion that "it is unlikely that a single platform can meet the interaction needs of this joint activity." Instead, it serves as a concept for scaffolding PBL approaches, suggesting a framework that integrates several practices and learning qualities such as collaboration, interaction, and sharing. Additionally, it proposes an innovative approach to facilitate the process of PBL learning, which does not rely on a "gold standard PBL" practice (as stated by [9]), but aims to pave the way for methods that motivate and stimulate students to learn through exploration, questioning, creation, and sharing.

The initial assumption was further investigated by showcasing how the methods inherent in PBL can be implemented through the steps of producing a virtual gallery. To present these steps, a diagram (illustrated in Figure 1) was created. In this context, it is suggested that the main problem (or parts of it) can serve as the central topic of the gallery, while the sub-tasks aimed at solving the problem can be seen as the artifacts of the gallery. In this way, students gain an understanding of the specific tasks that must be solved, which facilitates the identification of emerging requirements and underpinning needs. This is also in line with [11]'s suggestions regarding the online implementation of PBL and the use of virtual tools that encourage learners to immerse themselves and engage in collaborative problem-solving tasks. Tools included in [21] can support various activities toward the production of the virtual gallery and its contained artifacts.

Some proposed strategies include the integration of mechanisms typically used for organizing galleries. These are the addition of section titles, short texts, and directional signs, as well as dividing the gallery space into several rooms (encouraging segmentation and categorization by topic). Teachers may propose these mechanisms to help students more effectively identify the needs that must be addressed through the created artifacts. The spatial segmentation, along with the freedom for students to use tools and techniques that match their skills and talents, can facilitate role allocation. In addition, by encouraging students to use familiar tools and techniques, the virtual gallery method brings forward the application of existing knowledge and skills to the acquisition and development of new ones.

Some virtual galley creation tools, such as Artsteps, have limitations regarding collaborating on a 3D model and monitoring real-time changes made by another team member. These drawbacks can be overcome by implementing strategies such as virtual or in-person meetings of the team, or by using the same account to work on a shared 3D model in a rotational manner. Another aspect that has emerged is the opportunity for social interaction not only between students, but also among those who are invited to visit and explore the gallery. This may lead to the development of new forms of meaningful and interactive learning. The addition of the spatial dimension to problem-solving is another interesting aspect that is stressed, which brings into play embodied parameters such as interaction and navigation. It is argued that this factor may increase the students' confidence in finding ways to represent their ideas and experiment with different narrative mechanisms for proposing potential solutions, since they are engaged in learning processes that create among others a sense of presence.

5. Conclusions and Future Directions

This paper has identified a gap in the current literature concerning the absence of a conceptual framework that can facilitate and scaffold the learning process through the lens of PBL, in both physical and distance educational environments. In this context, it is argued that the concept of virtual galleries can provide this framework by serving as a learning scaffold for promoting PBL. It is a strategy that helps learners to better comprehend a given problem and identify its emerging needs. This is achieved through the segmentation of the problem into discrete tasks and transforming them into tangible artifacts. In addition, it is a method that enables the exchange of ideas and collaboration in both physical and online settings, while offering straightforward and progressive steps toward problem solving at both individual and team levels. Thus, it is perceived as an effective approach that gradually familiarizes learners with the PBL concept. Furthermore, it is a method that makes use of existing knowledge and skills to acquire and enhance new ones, by motivating students to employ tools and techniques that align with their individual interests and capabilities. This parameter, along with the integration of spatial dimensions, can also facilitate role allocation. Integrating spatial dimensions into problem solving transforms the entire process into a tangible and interactive procedure that incorporates embodied parameters such as navigation and interaction, thereby potentially heightening the learner's sense of presence. This may also enhance their understanding of how to deploy their proposed solution, so as to generate a meaningful narrative experience. Moreover, virtual galleries have the potential to enhance the learning experience and facilitate collaborative problem-solving, as they provide educators and other peer-learners the opportunity to explore and evaluate the presented content within the virtual environment.

Overall, it is argued that the concept of virtual galleries represents a promising approach for facilitating the implementation of PBL in both physical and distance learning environments, and it can foster methods that inspire and encourage students' self-driven learning. To verify this assertion, forthcoming research will concentrate on experimentally deploying this concept within the context of science education, in order to evaluate and assess the impact of this approach. Limitations regarding software features for online collaboration should be further investigated, while also considering alternative solutions and emerging software. The incorporation of the spatial dimension, along with certain embodied parameters, is promising and opens prospects for future research in this direction (including the role of embodied experience in the acquisition of knowledge within 3D virtual learning environments).

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