Instructional Design Model for Virtual Reality: Testing and Participant Experience Evaluation

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Abstract. This study aimed to test an Instructional Design model prototype for Virtual Reality (VR) in Higher Education. A qualitative research methodology was used, employing questionnaires and observations for data collection. The research had three main objectives: (1) to identify the applicability and effectiveness of the VR Instructional Design model, (2) to evaluate participants' experience with immersion, interactivity, and usability of the VR environment, and (3) to obtain feedback from participants about their VR experience. The study involved two sessions. In the first session, participants were introduced to the VR environment, and their initial adaptation difficulties were observed. Informal interviews and a questionnaire collected feedback on immersion, interactivity, interest, and educational potential of VR. The second session indicated the need for revisions in applicability and ease of use. Based on student feedback, session planning should consider initial adaptation, teacher training, equipment availability, interaction elements, resources, realism, immersion, safety, comfort, session duration, communication, collaboration, and clear content delivery. Providing alternative plans for technical failures is essential. Despite these challenges, participants expressed interest in participating in VR sessions and activities.

Keywords: Virtual Reality · Immersive Learning · Instructional Design · Higher Education

1 Introduction

The use of Virtual Reality (VR) as a teaching tool has sparked great interest in the field of education due to its potential to create immersive and interactive experiences. However, to ensure the effectiveness of this technology in pedagogical practice, it is essential to develop suitable Instructional Design models that align with the principles of instructional design and educational technology standards.

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This work reports on the test of a prototype Instructional Design model for Virtual Reality, using a qualitative research methodology. The tests aimed to identify any missing aspects or shortcomings of the model, through observation of potential difficulties or constraints, as well as identifying is advantages as expressed by participants when using VR in education. The study was conducted in a Higher Education undergraduate program, specifically in the ICT and Basic Education course. It consisted of two sessions, the first aimed at familiarizing students with Virtual Reality, the second providing an immersive classroom experience using Horizon[1].

Data collection was carried out through questionnaires and observation notes, with the intention to: (1) identify the applicability of the Instructional Design model developed for Virtual Reality; (2) evaluate the participants' experience regarding immersion, interactivity, and usability of the VR environment; (3) obtain feedback from participants about their experience with Virtual Reality.

2 Background

Virtual Reality, an image processing technology that allows users to experience being surrounded by a synthetic environment [1, 2], i.e., feeling perceptually "immersed" in a computer-generated world, has been applied as a pedagogical tool, with various rationales such as to enhance learning outcomes or providing context and focus [1, 3].

In these virtual reality environments two complex phenomena co-occur: learning and immersion [4]. Immersion is understood as more than just the visual perception of feeling present amidst a space. It also refers to a state of deep mental involvement (or absorption) with a narrative or an activity. In the context of learning, immersion can thus help students in multiple ways: they can benefit from the spatial interaction modalities, they can find meaning from the immersion with the narrative, and they can focus and engage more deeply via the immersion with their activity potential ("agency") [4].

Instructional design aims to ensure the quality of instruction, making it more efficient, effective, and less challenging. It involves activities such as needs analysis, defining learning objectives, establishing evaluative goals, and determining specific outcomes for successful learning. Instructional design bridges learning theories with the practice of developing instructional systems [8, 9].

The introduction of such immersive learning environments has brought new challenges and concepts, including the ability to assess the relevance and purpose of digital information, the need for communication skills in digital environments, skills to create multimedia content and programming, the ability to adopt security and sustainability measures in data protection, and the ability to solve problems and adapt digital resources for different purposes [5], raising questions about the application of instructional design in this context, as it provides guidance to teachers on how to develop and optimize the learning process [6, 7].

[1] Social virtual reality collaboration software environment (https://forwork.meta.com/horizon-workrooms/).

3 Context

3.1 REVEALING Project

This study was conducted as part of the REVEALING project, which falls under the Erasmus+ initiative (Erasmus + Project REalisation of Virtual rEality LearnING Environments (VRLEs) for Higher Education). The primary objectives of the project are as follows, and this led us to attempt developing an instructional design model for immersive virtual reality:

- Design and implement VRLEs (Virtual Reality Learning Environments) tailored to the needs of Higher Education Institutions (HEIs).
- Create pilot lessons using virtual reality (VR) technology.
- Develop a comprehensive guideline manual on the utilization of VRLE resources.
- Establish a VRLE Resource Directory to facilitate the incorporation of VRLE-compatible resources in HEI education.
- Empower teachers and students in HEIs to utilize innovative educational approaches with VR technology.

3.2 Prototype of the Instructional Design Model

These prototype tests aimed to identify any missing aspects or shortcomings of the instructional design model, through the observation of potential difficulties or constraints, as well as advantages expressed by participants when using VR in education. Our prototype of an Instructional Design Model comprises several planning phases, which include defining learning objectives, establishing the learning scenario, designing the environment, and selecting agents or actors. The session planning matrix encompasses various elements such as phase/time, learning objectives, key content/principles, methodology, resources, student activities, and assessment. The model draws on other theoretical models and frameworks to assist in defining these components, as follows: Bloom's taxonomy [10] guides the definition of learning objectives, while the methodology incorporates various pedagogical methods to support the learning process, including expository, demonstrative, active, and collaborative methods [9, 11, 12]; Merrill's instructional principles [13] are utilized to support instructional design; for the assessment component, models such as Boud's [14] "sustainable assessment" or the PRACT model from the Portuguese Open University are followed, proposing tasks that consider students' attitudes, knowledge, and skills/competencies, as well as the feasibility of their implementation by teachers [15]. We also considered previous studies, particularly the Standards of the Association for Educational Communications & Technology for Instructional Design in distance education [16, 17]. These standards encompass 10 key elements for learning design models, crucial to ensuring the effectiveness of the teaching and learning process, including Purpose, Assumptions, Sequence, Activities, Resources, Application of new learning, Ongoing/formative assessment, Reflection, Independent learning, and Evaluation.

Furthermore, to complement this Instructional Design model, the definition of learning scenarios is considered a distinct element compared to traditional teaching within the context of Virtual Reality. A learning scenario encompasses decisions related to

the design of the environment, the agents or actors involved, the sequence of tasks or activities, and the monitoring process of teaching and learning. The planning matrix for the sessions includes various elements such as topic, phase/time, location, duration, learning objectives, key content/principles, methodology, resources, student activities, and assessment.

Overall, our Instructional Design model is drawing from various theoretical frameworks and models, to support effective planning and execution of VR lessons, promote student engagement, and facilitate meaningful learning experiences.

3.3 Prototype Testing Sessions

The prototype testing sessions were scheduled for students of the ICT and Basic Education course of the bachelor's program in Basic Education at the University of Aveiro. The class consisted of 22 students, with 14 attending the first session and 8 in the second session.

ICT and Basic Education is an optional course offered as part of the program. The course takes place in the 2nd semester of the 3rd year, and the tests were held during the academic year 2022/2023. The course spans 13 weeks, with half of the classes conducted in person and the other half delivered through synchronous videoconference sessions using the Zoom platform. Additionally, there are asynchronous activities on the LMS Moodle and the Seesaw platform[2], practical workshops with guest speakers, and autonomous work sessions. The course awards 4 ECTS credits.

The objectives of this course are to develop digital skills and pedagogical knowledge in students by involving them in a project that integrates ICT in Basic Education. The teaching methodology includes Project-Based Learning (PBL), where students are divided into groups and work on projects that integrate ICT into the curriculum of Pre-School Education or Basic Education. The groups present their projects in stages, submitting different parts as they progress. In the academic year 2022/2023, the course had 22 students, including 4 Erasmus students, forming 6 teams. The teams were given the freedom to choose their project theme and determine the level of Basic Education to which it applies (e.g. primary, grammar, lower high school, ages approx. 6–14).

The first session, held on May 5, 2023, lasted for 90 min and had the following objectives: (1) familiarize students with the REVEALING project and the application of Virtual Reality in educational contexts; (2) provide hands-on experience with Virtual Reality using the Oculus Quest 2 headset; (3) engage in activities related to virtual learning scenarios and gather suggestions for their creation; and (4) initiate discussions about the virtual reality experience and reflect on its potential.

The session commenced with a Kahoot[3] questionnaire to assess participants' knowledge and understanding of key project concepts. A brief presentation of the project followed, covering the main points. The practical part involved dividing the class into small groups and focusing on the use of the Oculus Quest 2 headset. Some participants engaged

[2] The Seesaw platform revolutionizes interactive and engaging learning experiences for students, educators, and parents through its innovative digital tools and communication features (https://web.seesaw.me).

[3] Game-based learning plataform (https://kahoot.com/what-is-kahoot/).

in a game, while others experienced a "visit to the bottom of the sea," which is one of the scenarios developed within the REVEALING project. As there were only two headsets available, additional activities were organized to ensure everyone remained engaged. Three activities were thus conducted: an Escape Room to explore other scenarios developed for the project, a Digital Puzzle featuring the project's logo, and an Augmented Reality Exercise that incorporated objects and concepts related to the project. Each group participated in one of these tasks.

The session concluded with participants using Quizalize[4] to vote again, this time linking terms to their correct associations. A debate was also initiated with the students to gather reactions and feedback about the experience. Finally, the participants completed a form on Survio[5] to share suggestions and feedback about their experience.

It's important to note that this session was conducted in person, focusing solely on the use of Virtual Reality (VR) technology for the "First Steps" tutorial [6]and the presentation of an example virtual room in VRChat[7] (Fig. 1).

Fig. 1. Oculus Quest 2 Experience. Source: authors' photos.

In this second session, the plan was for the entire session to take place exclusively in the Virtual Reality environment using the headset. The second session took place on May 26, 2023, after the participants had become familiar with VR. In this session, approximately 9 participants were divided into groups of 2 and allocated 15-min sessions each.

During this session, the prototype of the Instructional Design model, described in Sect. 3.2, was used to support instructional design.

The objective of the session was to present the basic concepts of Instructional Design, explore its importance in creating educational materials, and demonstrate techniques and

[4] Quizalize is an online platform that provides teachers with tools to create engaging quizzes and assessments for students (https://www.quizalize.com).

[5] Survio is an online survey and questionnaire platform (https://www.survio.com).

[6] "First Steps" oculus tutorial (https://www.youtube.com/watch?v=tLsAnrsXoxA).

[7] VRChat is an online social platform that allows users to create and customize their own avatars and worlds, and then interact with others in virtual reality. (https://hello.vrchat.com).

strategies used in the field. The second session was conducted Horizon, as previously mentioned.. The session consisted of a theoretical exposition of Instructional Design and a practical segment where participants planned a session for primary education on the water cycle, based on the instructional design model.

The plan for this second session was to conduct the entire session exclusively in the Virtual Reality environment, using the headset (Fig. 2).

Fig. 2. Horizon Class Experience. Source: authors' photos.

4 Methodology

To test the prototype of Instructional Design for Virtual Reality, a qualitative research methodology was adopted, involving data collection through questionnaires and observation notes with distinct purposes and questions across the sessions. The first session had 14 participants, while the second session had 9 participants.

The research aimed to achieve the following objectives:

1. Identify the applicability of the developed Instructional Design model for Virtual Reality.
2. Evaluate the participants' experience concerning immersion, interactivity, and usability of the Virtual Reality environment.
3. Gather participants' feedback on their Virtual Reality experience.

The data collected through questionnaires and observation notes were analyzed to gain insights into the effectiveness and user experience of the Instructional Design model within the Virtual Reality context.

During the initial session to familiarize participants with virtual reality, the goal was to observe and record the initial difficulties they encountered when adapting to the VR environment. For this purpose, a questionnaire was administered to collect feedback from participants about the first session, focusing on immersion, interactivity, interest, and educational potential of VR. Informal interviews were also conducted after the VR experience, addressing the following questions:

1) *What were the main difficulties you encountered when using the motion controllers during the VR lesson?*

2) *How did you interact with the virtual elements during the VR experience? What were your actions and reactions?*
3) *How immersed did you feel in the VR environment? What elements contributed to that sensation?*
4) *In what aspects was the VR experience realistic? Were there any aspects that you found unrealistic?*
5) *How would it be for you to participate in a VR lesson, and what precautions would be necessary to ensure your safety and comfort?*

During the second session, where the Instructional Design model was applied in session planning, the aim was to verify the applicability of the model and assess its effectiveness by observing participants' interaction with the VR environment and collecting feedback through a questionnaire administered via a form. The questionnaire addressed the following aspects:

1) What were your expectations regarding the VR lesson before participating? Were these expectations met? Why?
2) In terms of immersion and realism, how would you evaluate the VR lesson experience? Did it meet your expectations? If not, what did you expect to be different?
3) Considering interaction with the virtual environment and other participants, how would you evaluate the ease of communication and collaboration during the lesson? Were there any aspects that could be improved in this regard?
4) Regarding the quality of the content presented in the lesson, do you consider that the information was conveyed clearly and comprehensibly? Was there any specific point that could be improved for better knowledge assimilation?
5) Thinking in terms of comfort and practicality, how do you evaluate the use of virtual reality equipment during the lesson? Did you experience any physical discomfort or obstacles that interfered with your experience? If so, how do you believe these aspects could be improved?

The questionnaires and records allowed obtaining information about participants' experiences, perceptions, challenges faced, and suggestions to enhance the use of VR in education. The collected data will be analyzed to make adjustments and future improvements to the instructional design and implementation of VR lessons in Higher Education Institutions (HEIs).

During the sessions, a content analysis was conducted using various themes to gather valuable insights [18]:

1st Session:

1. Challenges with the Virtual Reality Tutorial Session
2. Difficulties with Motion Control Usage
3. Challenges Prior to Instructional Design Implementation
4. Interest in Participating in Virtual Reality Classes
5. Difficulties Reported after the VR Experience (Interview)
6. Interaction with Virtual Elements During the VR Experience (Interview)
7. Sense of Immersion in the VR Experience

8. Realism of the VR Experience
9. Precautions Necessary for VR Classes

In these themes, challenges faced by participants during the virtual reality tutorial session were identified, including difficulties with motion control and other technical issues before the implementation of instructional design. Additionally, students' interest in participating in virtual reality classes was assessed, as well as difficulties reported after the VR experience in interviews, highlighting the interaction with virtual elements and the sense of immersion and realism during the experience. Precautions necessary for conducting VR classes were also discussed.

2nd Session:

1. Students' Expectations for the Second Virtual Reality Session
2. Communication and Collaboration During the Virtual Reality Class
3. Quality of Presented Content
4. Comfort and Convenience
5. Additional Observations Collected through Observation Notes

In the second session, the themes focused on students' expectations for the virtual reality experience, including communication and collaboration during the class. The quality of presented content and the comfort and convenience offered by the technology were also evaluated. Furthermore, additional observations collected through observation notes addressed various issues, including technical difficulties and students' preferences for in-person classes.

5 Presentation and Analysis of Results

5.1 1st Session

During the Virtual Reality orientation session (1st session), students were asked several questions, with a focus on issues such as "*Today, during the VR headset orientation, what were the biggest difficulties you encountered?*" The aim was to identify the main challenges faced while getting acquainted with the VR headset. Regarding the primary difficulties encountered when using motion controls during the VR experience, participants mentioned initial adaptation, understanding the commands, and locating the buttons "*I had difficulty only at the beginning to familiarize myself with the controls, especially in knowing where the buttons were*". Some participants also expressed difficulty in grabbing specific objects.

Regarding the question *"Thinking about the implementation of Instructional Design and a class in this environment, what previous difficulties do you identify?"* The responses pointed to challenges related to initial adaptation, teacher training, equipment availability, interaction among participants, and proper utilization of VR resources. Some examples: *"Initial adaptation and training for the teachers"; "I think the only difficulty could be the space-number of children relationship"*.

Furthermore, in line with the context, participants were asked if they were interested in participating in classes using Virtual Reality. The responses demonstrated a general interest in attending classes through virtual reality, mainly due to interactivity, dynamism, and the potential to make classes more engaging and interesting. However, it was also highlighted that certain aspects of learning may be better explored in the real world. Examples: "*I want to learn in a different way.*"; "*Because they will be more dynamic and interesting classes.*"

Concerning the observation notes with participants after the VR experience, similar to the responses to the questionnaire, the main difficulties encountered were in using motion controls and interacting with virtual elements: "[He/She] *had difficulty in grasping the objects.*"; "*Difficulty in clicking the button because* [he/she] *doesn't think it is well explained how to click.*"

The need for necessary precautions to ensure user safety and comfort was also emphasized, e.g.: "[He/she] *was afraid of getting dizzy but wanted to keep participating in the Oculus constantly.*".

Regarding interaction with virtual elements during the VR experience, participants described a variety of actions and reactions. They explored the virtual space, danced with the animated character from the tutorial, used virtual objects such as weapons, and interacted with elements present in the scene. Example: "[He/she] *enjoyed dancing with the character, and everything was intuitive*."

Considering the sense of spatial immersion in the VR environment, participants reported feeling immersed primarily due to the ability to move around, the quality of sound, and the ability to see their own hands. Interaction with virtual objects also contributed to the sense of spatial immersion: "[He/she] *felt immersed, what* [he/she] *saw, the sound, and seeing the hands.*".

Regarding the realism of the VR experience, participants considered the virtual room as the most realistic aspect. They mentioned the realistic response of the characters to movement, the ability to see their own feet, and the possibility of grabbing objects as elements that contributed to the realistic experience. However, some participants also pointed out that overall, the VR experience still does not fully compare to reality. Sample comment: "*The realistic objects and environment made* [me] *feel immersed.*"

Concerning participation in VR classes, participants showed interest and emphasized interactivity, dynamism, and the potential to make classes more engaging and interesting. However, they also highlighted the importance of certain classes or sections being conducted in the real world.

Regarding precautions necessary to ensure the safety and comfort of participants in VR classes, some participants mentioned concerns about possible dizziness and the need to use the headset with care. The importance of not immediately sharing with students the fact that they will be using the headset was also mentioned: "*It was very interesting, and* [he/she] *enjoyed exploring this aspect as a teacher.*"; "*It would be interesting to participate, and* [he/she] *would like to participate when* [he/she] *becomes a teacher.*"

5.2 2nd Session

The second session, focused on the application of the Instructional Design model in session planning, was planned to take place within the VR environment, specifically in a class on Instructional Design using the Meta Horizon Workrooms platform.

Regarding the responses, although there were few (4 answers), from the students to the questionnaire conducted at the end of the session, they indicate that their expectations regarding the VR class were generally met. They expected a tool to be used for short periods, and the activity carried out corresponded to their predictions. They also considered the environment immersive and satisfying in terms of spatial immersion and realism.

Regarding communication and collaboration during the class, students had ease in communication and collaboration, although one participant mentioned not having the opportunity to experience communication with other participants solely through the whiteboard (a resource available in the environment for writing their ideas about the exercise).

Regarding the quality of the content presented, students considered that the information was conveyed clearly and comprehensibly, without highlighting any specific points for improvement.

In terms of comfort and convenience, the virtual reality equipment was evaluated as practical and comfortable, with only a few difficulties mentioned regarding adjusting the device. However, no significant physical discomfort was reported.

However, the low expressiveness of the questionnaire responses may indicate that there were technical issues that affected the smooth development of the VR session. Issues such as low Internet bandwidth for three simultaneous devices, connectivity difficulties among participants in the same scenario, and the inability to share slideshows may have interfered with the students' experience. These technical aspects need to be addressed and improved to ensure a smoother and more satisfactory experience.

Additional observations collected through observation notes were also provided, revealing the difficulties encountered, including issues with writing on the virtual whiteboard ("*If you don't touch the table, the writing isn't continuous*"), auditory aspects ("*Confusion between sound in the Oculus and reality*"), "), technical glitches ("*Connectivity problems*"), time difference between speaking in reality and hearing in the other headsets, and additional comments regarding the practicality of the classes (*One student preferred in-person classes as Virtual Reality can generate distractions*).

In summary, students' expectations regarding the VR class were mostly met. Students appreciated the immersion, clarity of conveyed information, ease of communication and collaboration, and the comfort and convenience of the equipment. However, it is necessary to address technical issues to ensure a more consistent experience and improve interaction among participants.

6 Discussion

6.1 First Test Session – May 5th

Considering instructional design, it is possible to group the students' responses to obtain insights for improving the prototype. This enables identifying patterns and areas that need enhancement, resulting in a more efficient instructional design that is tailored to the identified needs in the use of VR.

Initial Adaptation: Participants mentioned the need for an initial adaptation phase to the VR environment and motion commands. This highlights the importance of providing an adequate introduction and clear instructions to help students become familiar with the environment and commands before starting the learning activities.

Teacher Training with the Hardware: Some responses indicated that participants faced difficulties related to using the motion commands and buttons. Therefore, it is important to ensure that teachers are properly trained in the use of the equipment and familiar with the functionalities of VR. This will enable them to provide support and guidance to students during the lessons.

Availability of the Equipment: Some responses mentioned concerns about the availability of the equipment, especially the Oculus headsets, for all students. The instructional design should take into account the available and necessary materials to ensure that all students have the opportunity to participate in the classes and benefit from the learning experience.

Interaction and VR Resources: Participants highlighted the interactivity and the ability to interact with virtual elements as attractive aspects of the VR experience. The instructional design should explore and incorporate these interaction features in a meaningful way, creating engaging activities and promoting active student participation.

Realism and Immersion: Participants described elements that contributed to the sense of spatial immersion, such as the ability to see their own hands and the realistic response of virtual objects. When designing VR lessons, it is important to consider these aspects and strike a balance between spatial immersion and the need for effective learning, taking into account the current limitations of the technology.

Safety and Comfort: Some participants mentioned concerns about dizziness when using the headset. The instructional design should consider safety measures and ensure that students are instructed on the proper use of the equipment, as well as provide adequate breaks and rest opportunities to minimize any discomfort. Therefore, the timing of the sessions should take this aspect into account.

In summary, the information gathered about the difficulties faced and the participants' perceptions regarding VR provide important guidance for instructional design. These insights help in planning learning experiences, considering initial adaptation, teacher training, equipment availability, interaction, and immersion, as well as student safety and comfort.

6.2 Second Test Session – May 26th

Time: Students expected the virtual reality class to be designed for short periods, and their expectations were met. This indicates that the instructional design was efficient in providing an experience that fit the available time and the content approach.

Immersion and Realism: Students positively evaluated the immersion and realism of the virtual reality learning experience with the Oculus equipment. The use of virtual reality as an instructional tool proved to be effective in creating an immersive experience for the students.

Communication and Collaboration: Students reported ease of communication and collaboration during the class, although one participant mentioned a lack of opportunity to interact with other participants beyond written communication (whiteboard). This information highlights the importance of designing activities that encourage interaction among students in virtual reality and provide clear opportunities for communication and collaboration.

Clear Transmission of Content: Students considered that the information was transmitted clearly and comprehensibly during the class. This reveals the importance of considering clarity in information transmission when planning VR training moments.

Comfort and Practicality: Students positively evaluated the use of virtual reality equipment in terms of comfort and practicality, with only a few difficulties mentioned in adjusting the device. This suggests the need to pay attention to device adjustment to provide a comfortable experience for students.

Again, the technical issues and limitations mentioned by students, such as low Internet speed and the inability to share slideshows, also have implications for instructional design. These technical issues need to be addressed and resolved to improve the effectiveness of instructional design in virtual reality.

In summary, the information gathered in the second session provides important guidance for instructional design, particularly regarding time planning, immersion and realism, communication and collaboration, clear transmission of content, and comfort and practicality.

7 Conclusion

A prototype of an Instructional Design for virtual learning environments using Oculus Quest 2 has been developed and tested. The instructional design model considers aspects such as defining learning objectives, content selection, activity sequencing, instructional principles, methodology, resources, student activities, and assessment. Tests and experiments were conducted with students and teachers to identify difficulties and constraints in the use and implementation of the model.

Preliminary results show that participants faced initial difficulties in adapting to the Virtual Reality environment, particularly with motion controls. However, they expressed interest in participating in VR classes due to interactivity and educational potential. Participants reported interaction with virtual elements, a sense of immersion, and the perception of the reality of the VR experience.

Regarding instructional design, it is evident that the difficulties encountered and the participants' perceptions regarding VR provide important guidance for instructional design, considering initial adaptation to the tool, teacher training, equipment availability, valorizing interaction elements and available resources, emphasizing realism and immersion, ensuring safety and comfort when using the equipment, session duration, communication and collaboration, as well as clear content transmission. Additionally, the importance of promoting alternative plans to address technical failures that may compromise the learning experience is evident.

Furthermore, it was concluded during the application phase of the instructional design model that it presents some difficulties in its completion. It was noticeable that the process is time-consuming, and without careful and prior reading of the explanatory guide, it becomes difficult to understand what needs to be defined at each point. This situation highlights the need to improve the process, as it may lead to user abandonment. Therefore, it was found that it would be more appropriate to include sections with auto-fill suggestions and concise explanatory messages.

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