To cite this version :

Pierre BONDESAN, Teerawat KULSUWAN, Yoan LOCARD, Sylvain FLEURY, Andréa BOISADAN, Cyrille BAUDOUIN, Simon RICHIR - Empowering Instructional Design Research: Open-Access Experimental Materials - In: International Conference on Information and Education Technology, Japon, 2025-04-18 - Proceedings of 2025 13th International Conference on Information and Education Technology (ICIET 2025) - 2025

Empowering Instructional Design Research: Open-Access Experimental Materials

Pierre Bondesan
Angevin Laboratory of Mechanics, Processes, and Innovation
Institute of Technology Arts et Métiers
Changé, France
pierre.bondesan@ensam.eu

Teerawat Kulsuwan
Angevin Laboratory of Mechanics, Processes, and Innovation
Institute of Technology Arts et Métiers
Changé, France
teerawat.kulsuwan@ensam.eu

Yoan Locard
Angevin Laboratory of Mechanics, Processes, and Innovation
Institute of Technology Arts et Métiers
Changé, France
yoan.locard@ensam.eu

Sylvain Fleury
Angevin Laboratory of Mechanics, Processes, and Innovation
Institute of Technology Arts et Métiers
Changé, France
sylvain.fleury@ensam.eu

Andréa Boisadan
Digital Innovation Laboratory for Enterprises and Learning
School of Engineering CESI
Nanterre, France
aboisadan@cesi.fr

Cyrille Baudouin
Laboratory of Design, Manufacturing, and Control
Institute of Technology Arts et Métiers
Metz, France
cyrille.baudouin@ensam.eu

Simon Richir
Angevin Laboratory of Mechanics, Processes, and Innovation
Institute of Technology Arts et Métiers
Changé, France
simon.richir@ensam.eu

***Abstract*—Educational technologies are increasingly used in education but it remains challenging to demonstrate their effectiveness by employing evidence-based research (EBR). This article presents an open-access experimental resource for Instructional Design and Technology (IDT) studies. The resource includes a Unity application in VR and desktop format with instructional content and tools to display it. It also provides assessment instruments to measure declarative and procedural knowledge. This material allows researchers to test various instructional design elements and explore multimedia learning principles. The content is based on an engineering theme and is suitable for higher education students, including those without a STEM background. This paper also details the co-design process and preliminary testing with ten participants. We encourage researchers to freely adapt the application, content and assessment tools to meet the needs of their study. This initiative invites research groups to share similar experimental resources for other fields to make IDT research more accessible.**

Keywords— instructional design, multimedia learning, virtual reality, evidence based learning

I. Introduction

A. Instructional Design and Technology Research

Two complementary approaches stand out in the field of Instructional Design and Technology (IDT) research: Evidence-Based Research (EBR) and Design-Based Research (DBR). EBR is grounded in an experimental approach. This method involves changing a single instructional element to demonstrate its impact on learning outcomes. The advantage of this approach is based on the robustness of its results obtained through inferential statistical analysis comparing an experimental group and a control group. Thus, it is possible to identify learning principles effectively and ground them in theoretical models. One extensively used theory is multimedia learning, which combines verbal narration with animated visuals to help learners select, organize, and integrate new knowledge [1]. Over the last three decades, this theory has established core instructional design principles for content delivered via slideshows [2], computer-based environments [3],immersive virtual reality [4], and virtual agents [5].

Evidence-based research may encounter limitations when applied to authentic educational settings, as it often overlooks specific contextual factors [6], [7]. In contrast, DBR follows an iterative process in which educational tools are co-developed with teachers and learners to suit a specific use case [8]. This approach has gained popularity in computer-based learning research [9]. Nonetheless, the weakness of the DBR method is its inability to demonstrate the effectiveness of a particular instructional design element, as it involves no control group and combines multiple variables. This limitation of the DBR approach makes the results difficult to generalize across the entire field of IDT research [10].

In contrast to DBR, the EBR approach requires rigorous standardization of the materials and protocols used, which can make it challenging to implement..This article introduces research materials for IDT research rooted in the EBR approach. We believe that providing open-access experimental materials is essential to facilitate research for the scholarly community working on educational technologies.

This project was funded by the French National Research Agency (ANR) under the JENII project.

B. *Challenges in Instructional Design and Technology*

Producing technology-enabled materials for IDT research is challenging as it requires a multidisciplinary team: developers to design virtual environments, learning specialists to guarantee instructional effectiveness and content experts to ensure accuracy. The process of developing, testing, and refining this material is time-consuming, and each new project must often start from scratch. This issue makes research materials less accessible, especially for teams with smaller budgets or less focus on tech innovation.

Another challenge in IDT research is prioritizing technology development over research questions. A review conducted in the United Kingdom revealed that just 7% of educational technology companies had carried out randomized controlled trials to assess their effectiveness [11]. This lack of methodological rigour is particularly apparent in research on immersive learning as shown by low scores on quality assessment tools for educational research [12], [13]. Often, these studies have no control group, making statistical analysis impossible. A meta-analysis showed that nearly two-thirds of these studies are conducted without a well-defined theoretical framework [14]. In addition, most studies focus on learning experience but do not assess knowledge acquisition [13], [14]. Even when learning is assessed, evaluations are often limited to knowledge retention [13]. These gaps slow progress on key questions, such as whether immersion improves learning more effectively than traditional media and which learning goals best fit immersive environments.

Finaly, many research projects develop educational tools specifically adapted to particular contexts rather than creating experimental materials, which makes replication challenging. This variability often results in diverse protocols and outcomes, complicating interpretation and limiting a shared theoretical framework [15]. While some research groups reuse experimental materials with minor modifications [16], [17], [18], the lack of standardized research materials restricts study comparability.

C. *Objective*

This paper introduces an open-access experimental material based on an industrial forge simulation to support IDT research. This material was co-developed by a multidisciplinary team, including subject-matter experts, 3D developers, and educational psychology researchers. The material was also tested on higher education students. The material features a multimedia virtual environment, accessible in both desktop and immersive virtual reality formats. Tools are also provided to record avatars, voices, and interactions within the environment. In addition, the materials include narrative lesson content and assessment content. These assessments measure various knowledge types and levels. Even though the material was designed around an engineering theme, the content is accessible even for learners without a specific STEM background. Thus, Researchers can freely modify this experimental material to suit their needs and use it to conduct their own instructional design studies.

II. EXPERIMENTAL MATERIAL PRESENTATION

A. *Rationale of the Material*

The experimental material involves a lesson of the forging procedure of a metal piece using a screw press in a virtual environment. This theme was chosen for its authenticity, as it replicates an actual forging cell located on the campus of a French engineering school. Representing a physical location allows spatial context for knowledge acquisition, which is particularly valuable in STEM education [19].

Additionally, this theme was selected for the range of knowledge types it supports. It allows for the assessment of declarative knowledge, defined in Bloom's taxonomy as the understanding of facts, concepts, and principles [20]. The material also enables the evaluation of procedural knowledge, which Bloom's taxonomy defines as applying specific skills and methods [20].

B. *Narrative Content*

The narrative content covers the sequence of five steps involved in forging a titanium billet. Each stage includes procedural elements (e.g., putting on protective equipment, starting the furnace, and adjusting the machine) as well as declarative elements (e.g., defining a billet and explaining the concept of kinetic energy). The narrative is not directly integrated into the application but is available as an English-language script. Several tools have been provided to enable researchers to implement the narrative content according to their needs.

Fig. 1. Virtual tablet interface for step-by-step forging instructions

The narration can be integrated into text form using a virtual tablet available in the environment (Figure 1). This tablet displays instructions step-by-step, with arrows to move to the next or previous step. A progress bar informs learners of their advancement through the content. A question mark button highlights specific areas within the environment, indicating to the learner the precise location relevant to the current instruction.

Narration can also be integrated into an auditory and dynamic format using the immersive sequence recording tool. This tool offers two modes: recording and playback. The recording interface captures avatar movements, voice, and interactions with the environment (Figure 2). Multiple recordings can be created to segment the content. Management features like pause, validate, and delete are available to facilitate recording control. The playback interface allows the learner to select and play a recording (Figure 3). Additional playback controls include pause, rewind, and fast-forward.

Fig. 2. Recording interface for capturing avatar interactions

Fig. 3. Playback interface with controls for revising recorded sequences

The tools are designed to be user-friendly, requiring no development skills and being directly accessible in the application. Both tools are designed to help researchers integrate narrative content into the environment in the language and manner they choose, though they are not exhaustive and can be deactivated in the project code.

C. The Virtual Environment

The virtual environment is accessible through a Unity application, developed as both an immersive virtual reality and desktop application. Users can interact freely just as they would in the real world through the embodiment of an avatar. The avatar's appearance can be imported from any Ready Player Me model. They can equip safety gear, configure machines, and operate them. In certain areas, it is also possible to activate or deactivate cross-sectional views to observe the internal mechanisms of the machines.

This application is designed as a blank environment without embedded narration. The environment does not impose a fixed path, allowing researchers to customize it according to their needs.

D. The Assessment Content

The assessment content measures both declarative and procedural knowledge. Declarative knowledge is evaluated through a knowledge questionnaire, while procedural knowledge is assessed using observation grids. These grids require the learner to return to the virtual environment to complete specific instructions.

The assessment instruments account for different levels of knowledge, from basic memorisation to application in new context. There are six levels of cognitive knowledge: remembering (basic memorization of facts), understanding (grasping meaning), applying (using information in new contexts), analysing (breaking down information to explore relationships), evaluating (judging based on criteria), and creating (generating new ideas or products) [20]. Each lesson segment includes specific questions to assess declarative knowledge, covering memorisation, comprehension, and application. The instructions for the procedural knowledge assessment involve a scenario assessing memorisation and a scenario assessing application in new context. Table 1 provides an overview of the knowledge assessed according to Bloom's taxonomy.

TABLE I. OVERVIEW OF COGNITIVE KNOWLEDGE LEVELS ASSESSED

Knowledge type	**Cognitive knowledge levels**		
	1.Remember	***2.Understand***	***3. Apply***
Declarative knowledge	X	X	X
Procedural knowledge	X		X

III. CO-DEVELOPMENT AND EVALUATION OF THE MATERIAL

This material was developed through collaboration among industrial forging experts, learning specialists, and 3D developers. Initially, the application was part of a project to create digital replicas of real environments for engineering training and is currently used in engineering [21]. Using the virtual environment and cases designed by the forging experts, a lesson on forging was created to be accessible to higher education students without specific STEM backgrounds.

A. Educational Content Creation

To ensure the content's scientific accuracy, instructional experts with a mechanics of materials expert experienced in teaching with a real industrial forge environment conducted a recorded semi-structured interview. The interview was based on an existing scenario describing the forging procedure of a metal piece using a screw press. It aimed to collect detailed explanations about the reasoning behind each step and the physical phenomena involved. The semi-structured format allowed the expert to provide in-depth explanations, guided by targeted questions such as, "How does the screw press work?" or "Why perform multiple consecutive strikes?"

The instructional experts also attended a forging demonstration in a real industrial forge. During this demonstration, the expert provided explanations and answered questions. A second forging demonstration was then conducted in the immersive virtual environment.

The interview was transcribed and formed the basis for a narrative script structured into five parts. Using this new scenario, questions assessing declarative knowledge were created to evaluate memorization (e.g., "What is the name of the object used as raw material in forging?"), comprehension (e.g., "Explain the difference between force and energy"), and application (e.g., "Two cars, A and B, collide head-on. After impact, car A shows severe front-end damage with visible folds and deformations, while car B only has minor dents. Which driver is more at risk, and why?").

Procedural knowledge is assessed using two observation grids. The first grid evaluates the memorisation by asking the learner to reproduce the procedure. The second grid evaluates application by asking the learner to adapt the procedure to a different type of material.

B. *Educational Content Pre-test*

A pre-test on the educational content was conducted to refine assessment questions and ensure the material was suitable for a higher education audience with diverse backgrounds. The test focused on improving questions that assess declarative knowledge. This step is essential for effective discrimination of learning outcomes between groups in comparative studies.

Ten french participants with higher education backgrounds and varying academic profiles agreed to participate in this test phase. First, participants completed a questionnaire on their sociodemographic profile and prior knowledge of the lesson topic. The prior knowledge questionnaire was adapted from Parong's material [16]. Next, participants watched a 17-minute video covering the entire lesson content (figure 4). This educational video was recorded by an instructor in the virtual environment using the immersive sequence recording tool described in the previous section and then edited for viewing. Twenty-four hours after watching the video, participants answered the declarative knowledge questionnaire. A 24-hour interval was chosen to avoid excessive immediate recall as a one-day gap typically leads to a natural information loss of about 50% [22].

Fig. 4. Educational video of the screw press lesson

Table 2 provides an overview of participant profiles. In experimental protocols comparing multiple conditions, it is recommended to use this questionnaire to ensure that initial variables do not differ between groups. The questionnaire showed Cronbach's alpha of 0.76. This result indicates a satisfactory to high level of internal consistency and suggests that the baseline data are reliable for comparison across groups. Results in Table 3 show an overview of participant performance in declarative knowledge for each lesson section. Some questions judged too easy or difficult were adjusted to improve internal consistency following this test phase. Questions with correct response rates below 33% were categorized as "difficult." Questions with correct response rates between 34% and 66% were categorized as "moderate." Questions with correct response rates above 67% were categorized as "easy." Detailed results on question difficulty levels and response times are available as supplementary material. A Pearson correlation of 0.34 was observed between previous knowledge and performance. This suggests a modest positive relationship, with higher prior knowledge associated with better performance. Researchers are advised to select questions based on the time available for their study and the prior knowledge level of their sample.

TABLE II. PARTICIPANT PROFILES AND BASELINE MEASURES (N=10)

	Mean (SD)
Age	25.2 (1.7)
Study (Years in Higher Education)	4.6 (0.8)
Gender (M/F)	7/3
Previous knowledge (out of 10)	3.9 (1.4)

TABLE III. PARTICIPANT PERFORMANCE IN DECLARATIVE KNOWLEDGE (N=10)

	Mean declarative knowledge score					
	Part 1	***Part 2***	***Part 3***	***Part 4***	***Part 5***	***Total***
Remember (total out of 9)	0.88	0.5	0.3	0.75	0	2.43
Understand (total out of 12)	1	0.85	1	1.55	0.55	4.95
Apply (total out of 11)	1.6	1	1.33	0.4	0.4	4.73

C. *Limitations of the Material*

The initial testing involved only French participants, which may limit its applicability in diverse cultural and educational contexts. Additionally, the evaluation method for factual knowledge could be improved, as the low average score (2.43/9) may not effectively capture differences in knowledge retention. Finally, the VR material requires a PC-connected VR headset, which is less accessible than standalone VR devices. Addressing these issues in future research will enhance the material's impact and accessibility.

IV. CONCLUSION

This article presented the design and testing of an experimental material for use in IDT research. The material includes a Unity application accessible in VR and PC formats, tools for recording avatar movements, interactions, and voice, a detailed instructional script, and a set of assessment instruments for measuring declarative and procedural knowledge. The material and all usage instructions are available at the following link: https://gitlab.ensam.eu/jenii-experimental-materials/screw-press-lesson.git.

This open-access material is designed for researchers interested in conducting comparative studies using an EBR approach. This material was designed to allow easy variation of instructional design elements. The material is also accessible to a wide range of studies, supporting the assessment of different types of knowledge in higher education without requiring a STEM background. This material is currently used to test various instructional design principles. For instance, one ongoing study explores different guidance levels through narration in the VR environment.

Ongoing challenges in the literature include exploring additional multimedia effects through evidence-based methodologies. Researchers are encouraged to modify the application, educational content, and assessment tools to suit their study objectives and share their adaptations through a GitLab fork. Another challenge lies in accounting for the diversity of learning contexts. Similar materials should be developed in other domains, such as language acquisition, social sciences, medicine, and soft skills development. We hope to foster a collaborative dynamic to enhance and make instructional design research more accessible.

Acknowledgment

The authors wish to thank the members of the Laboratory of Design, Manufacturing, and Control at the Institute of Technology Arts et Métiers for their expertise, particularly Camille Durand and Tudor Balan.

References

[1] R. E. Mayer, "Multimedia learning," in Psychology of Learning and Motivation, vol. 41, Elsevier, 2002, pp. 85–139. doi: 10.1016/S0079-7421(02)80005-6

[2] R. E. Mayer and V. K. Sims, "For Whom Is a Picture Worth a Thousand Words? Extensions of a Dual-Coding Theory of Multimedia Learning," Journal of educational psychology, 1994.

[3] R. E. Mayer, "Using multimedia for e-learning," Journal of computer assisted learning, 2017, vol. 33, no 5, p. 403-423. doi: 10.1111/jcal.12197

[4] R. E. Mayer, G. Makransky, and J. Parong, "The Promise and Pitfalls of Learning in Immersive Virtual Reality," International Journal of Human–Computer Interaction, pp. 1–10, Aug. 2022, doi: 10.1080/10447318.2022.2108563

[5] A. P. Lawson and R. E. Mayer, "Does the emotional stance of human and virtual instructors in instructional videos affect learning processes and outcomes?," Contemporary Educational Psychology, vol. 70, p. 102080, 2022, doi:10.1016/j.cedpsych.2022.102080

[6] A. Kaplan, J. Cromley, T. Perez, T. Dai, K. Mara, and M. Balsai, "The Role of Context in Educational RCT Findings: A Call to Redefine 'Evidence-Based Practice,'" Educational Researcher, vol. 49, no. 4, pp. 285–288, May 2020, doi: 10.3102/0013189X20921862

[7] P. M. Newton, A. Da Silva, and S. Berry, "The Case for Pragmatic Evidence-Based Higher Education: A Useful Way Forward?," Front. Educ., vol. 5, p. 583157, Dec. 2020, doi: 10.3389/feduc.2020.583157

[8] D.-B. R. Collective, "Design-based research: An emerging paradigm for educational inquiry," Educational researcher, vol. 32, no. 1, pp. 5–8, 2003. doi: 10.3102/0013189X032001005

[9] Y.-H. Wang, "Design-based research on integrating learning technology tools into higher education classes to achieve active learning," 2020.doi : 10.1016/j.compedu.2020.103935

[10] A. Parmaxi and P. Zaphiris, "Lessons learned from a design-based research implementation: a researcher's methodological account," International Journal of Research & Method in Education, vol. 43, no. 3, pp. 257–270, 2020. doi : 10.1080/1743727X.2019.1671327

[11] GEM Report UNESCO, Global Education Monitoring Report 2023: Technology in education: A tool on whose terms?, 1st ed. GEM Report UNESCO, 2023. doi: 10.54676/UZQV8501

[12] D. Hamilton, J. McKechnie, E. Edgerton, and C. Wilson, "Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design," J. Comput. Educ., vol. 8, no. 1, pp. 1–32, Mar. 2021, doi: 10.1007/s40692-020-00169-2

[13] L. Jensen and F. Konradsen, "A review of the use of virtual reality head-mounted displays in education and training," Educ Inf Technol, vol. 23, no. 4, pp. 1515–1529, Jul. 2018, doi: 10.1007/s10639-017-9676-0

[14] J. Radianti, T. A. Majchrzak, J. Fromm, and I. Wohlgenannt, "A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda," Computers & Education, vol. 147, p. 103778, Apr. 2020, doi: 10.1016/j.compedu.2019.103778

[15] J. A. Plucker and M. C. Makel, "Replication is important for educational psychology: Recent developments and key issues," Educational Psychologist, vol. 56, no. 2, pp. 90–100, Apr. 2021, doi: 10.1080/00461520.2021.1895796

[16] S. Klingenberg, R. Fischer, I. Zettler, and G. Makransky, "Facilitating learning in immersive virtual reality: Segmentation, summarizing, both or none?," Computer Assisted Learning, vol. 39, no. 1, pp. 218–230, Feb. 2023, doi: 10.1111/jcal.12741

[17] J. Parong, "Multimedia Learning in Virtual and Mixed Reality," in The Cambridge Handbook of Multimedia Learning, 3rd ed., R. E. Mayer and L. Fiorella, Eds., Cambridge University Press, 2021, pp. 498–509. doi: 10.1017/9781108894333.051

[18] J. Parong and R. E. Mayer, "Learning science in immersive virtual reality.," Journal of Educational Psychology, vol. 110, no. 6, pp. 785–797, Aug. 2018, doi: 10.1037/edu0000241

[19] J. Wai, D. Lubinski, and C. P. Benbow, "Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance.," Journal of Educational Psychology, vol. 101, no. 4, pp. 817–835, Nov. 2009, doi: 10.1037/a0016127

[20] L. Anderson, D. Krathwohl, "A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives," Addison Wesley Longman, Inc., 2001.

[21] S. Fleury, C. Baudouin, and P. Bondesan, "Immersive digital twins of an industrial forge in engineering education," 20th International CDIO Conference (CDIO 2024) : Engineering Education in The Era of AI, 2024, ⟨hal-04622716⟩

[22] J. M. J. Murre and J. Dros, "Replication and Analysis of Ebbinghaus' Forgetting Curve," PLoS ONE, vol. 10, no. 7, Jul. 2015, doi: 10.1371/journal.pone.0120644