



HAL
open science

SAMPO, a Scenario Authoring Model for Virtual Reality with Pedagogical Objectives: An Authoring Perspective

Mathieu Risy, Bruno Arnaldi, Valérie Gouranton

► **To cite this version:**

Mathieu Risy, Bruno Arnaldi, Valérie Gouranton. SAMPO, a Scenario Authoring Model for Virtual Reality with Pedagogical Objectives: An Authoring Perspective. Communications in Computer and Information Science, In press, 12. hal-04829546

HAL Id: hal-04829546

<https://hal.science/hal-04829546v1>

Submitted on 10 Dec 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

SAMPO, a Scenario Authoring Model for Virtual Reality with Pedagogical Objectives: An Authoring Perspective

Mathieu Risy^[0009-0004-6248-9988], Bruno Arnaldi^[0000-0002-9351-2747], and Valérie Gouranton^[0000-0002-2868-8826]

Univ. Rennes, INSA Rennes, Inria, CNRS, IRISA, France
`{first-name}.{last-name}@irisa.fr`

Abstract. How domain experts without expertise in VR development can be direct actors in the creation of Virtual Reality Environments for Training (VRET)? In order to facilitate a more hands-on approach to scenario authoring for domain experts, this paper proposes an extension of the Scenario Authoring Model with Pedagogical Objectives (SAMPO) for Virtual Reality. It expands SAMPO with accessible activity prerequisites, pedagogical guidance triggers, and learning activity selectors. This paper adopts the domain experts' authoring perspective to describe the authoring process.

Keywords: Virtual Reality · Scenario · Pedagogy · Authoring · Welding Use Case.

1 Introduction

The authoring of scenarios for Virtual Reality Environments for Training (VRET) is challenging for teachers and trainers. While VRETs offer compelling educational benefits [12], their authoring remains inaccessible without robust Virtual Reality (VR) development expertise [2]. As a result, they are typically developed by VR experts at the initiative of a domain expert (Figure 1a). We argue that domain experts should be able to author VRET scenarios directly (Figure 1b), as they are responsible for the pedagogy and have knowledge of the learning content.

In Virtual Environments, we consider that a scenario is a characterization of the events that can happen and requires monitoring. It can describe user actions, interactions, and the behavior of the environment. Every VR application contains scenarios, whether they are explicitly defined or unfold at runtime. Furthermore, as educational tools, VRETs include implicit or explicit pedagogical decisions. It is essential that domain experts have control over the integration of pedagogical elements within the environment to foster their autonomy in authoring VRET scenarios.

In current models, scenarios authored during the VRET development phase typically remain the only available options. We argue that a pedagogical tool

should be able to evolve according to the needs of domain experts and learners. Thus, domain experts should be able to author new scenarios to add to the application.

In previous work, we presented the Scenario Authoring Model with Pedagogical Objectives (SAMPO) [25] to allow domain experts to author pedagogical scenarios directly using VR-compatible pedagogical specifications. Its modular architecture enables the coexistence of multiple pedagogical scenarios to support pedagogical variability. It aims to foster the reuse and edition of a VRET during its life cycle to become an evolving educational tool.

In this paper, we propose an extension of SAMPO to ensure that authoring is a straightforward and logical process for domain experts. We propose an authoring perspective focusing on the scenario flow to illustrate how domain experts can create VRET scenarios tailored to their needs. Some of these contributions aim to respond to the limitations we set out in the previous work [25]. We present the authoring process of SAMPO, as a general workflow, and detail the authoring of each specification. This work is illustrated by a welding use case.

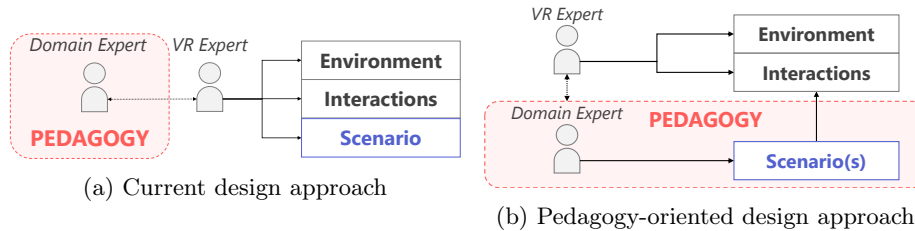


Fig. 1: Design approaches to Virtual Reality Training Environment (VRET)

2 Related Work

This section describes the integration of pedagogy in VRETs and highlights related work on scenario authoring for VRET.

2.1 Pedagogical Integration in VRET

Every Virtual Reality Environments for Training (VRETs) contains pedagogical decisions whether expressed explicitly or implicitly. Most VR and AR training applications do not state an explicit pedagogical approach, or guiding pedagogical principles [13,21,24]. Among the VRETs citing a specific approach, most refer to the learning theory of constructivism [22] or theories that derive from its principles. The prevalence of this theory can be explained by the compatibility of constructivist principles with the VR learning affordances [12]. It encourages engaging learners in contextualized experiential learning. A few works

prefer lecture-based learning which is less compatible with constructivism theories [6]. VR is also often used for short duration and lends well to micro-learning approaches. “*VR nugget*” [15] combines generic VR patterns such as “decomposing”, or “tagging” models to construct courses with on-demand VR interactions.

While learning approaches inform the educational design of a VRET, direct pedagogical authoring requires machine-interpretable pedagogical specifications. Planning a training session in a virtual environment is often done by segmenting it into interconnected learning activities [26]. The IMS Learning Design [18] “Play-Act-Learning Activity” structure has been integrated multiple VRET models [20,9]. More atomic description into tasks and actions [16,14,7] is also often used to model short interventions and precise procedures. Collaborative Virtual Environments (CVE) often model notions such as “Roles” [10] or “Teams/organization” [8] to represent differences between actors (role) in educational social contexts. These specifications model differences in resource access and behaviors for pedagogical agents or multiple users.

2.2 Pedagogical Scenario Authoring

Scenario authoring encodes the events that need monitoring and can unfold in a virtual environment. The expressivity of a scenario depends on the representation of virtual environment events and processes. Authoring learning scenarios embarks additional constraints centered on the learner experience in the VRET. Differences in representation often indicate differences in the educational goal or focus of the scenario type. This section discusses types of scenario authoring used in VRET and the variability they can offer.

Procedural scenarios specify sequences of events that can happen successively or concurrently [11]. They are often used in professional training to describe procedures as well-specified sequences of tasks and actions [14]. To overcome complexity and reusability issues caused by authoring only with primitives of the virtual environment, scenario models have proposed higher-level building blocks. Providing pre-planned interaction categories [9,15] can allow quick and easy authoring of a succession of simple actions, but is quickly limited to 3D-model manipulation. Enriching the environment with semantics created directly by domain experts adds custom behaviors and relations shared by elements with similar semantic properties [5]. They represent the environment behavior and are used as new atomic elements to author scenarios, like in the models GVT [14] or MASCARET [8].

Specifications representing domain-specific relations, such as semantics, are the basis of knowledge-based scenario models. Models like VR-WISE [17] use ontologies written by domain experts to define the semantics of the application. It allows the environment to act using domain-specific logic [8]. However, scenarios remain constrained by the procedural logic, which becomes unsuitable when the complexity explodes, or when intermediate steps are either unimportant or difficult to model.

On the opposite end, emergent scenarios rely essentially on domain-specific knowledge. They model only the behavior of the environment to let the scenario

emerge. In HUMANS [19], the pedagogical content is provided by agents' reasoning based on semantic information, causality, and domain knowledge. While this provides a reactive and ecological environment, pedagogical authoring is scarcely constrained by the domain expert.

Goal-based scenarios use goals as loosely connected scenario points that need to be achieved [23]. Goals are represented as constraints and specific states of the environment or the user. They are also often linked by causal links [7] and preconditions, like in Steve VRET [16]. Goal-based authoring provides a more familiar authoring language, while allowing the domain expert to keep pedagogical control over the situations.

The Assessment-based approach [26] is a specific type of goal-based approach that allows a more flexible authoring centered on pedagogical objectives. Progress within the scenario is conditioned by the validation of assessments defined by the domain expert. Thus, assessments, the scenario key points, can take multiple forms such as setting the environment in a specific state, providing a correct answer, or following the steps of a procedure.

2.3 Toward a scenario approach for VRET

Current VRET scenario models have been able to achieve ecological and complex learning environments. However, we have not yet identified models that allow for the complete authoring of VRET scenarios by domain experts, ensure pedagogical coherence, and support pedagogical variability.

To the best of our knowledge, very few assessment-based approaches exist, however, they present an interesting hybrid type of scenario authoring that is closer to domain experts' pedagogical practices. They show promising capabilities for a pedagogically coherent authoring model accessible to domain experts.

3 Use Case

SAMPO is constructed as a domain-independent model to apply to any educational context. Nonetheless, such a model must be instantiated to validate its approach with domain experts. This section describes the instantiation of SAMPO on a welding training application in VR that features three scenarios. This use case is then used to illustrate the properties of the model in the rest of the paper.

3.1 Welding Training Application in VR

The welding training application was designed in collaboration with domain experts who teach courses with actual welding practice. Its objectives are to introduce undergraduate students to safety practices and welding basics about Metal Inert Gas (MIG) welding.

The application features two environments that contain multiple pedagogical guidance, error handlers, and evaluations to allow domain experts to adapt the

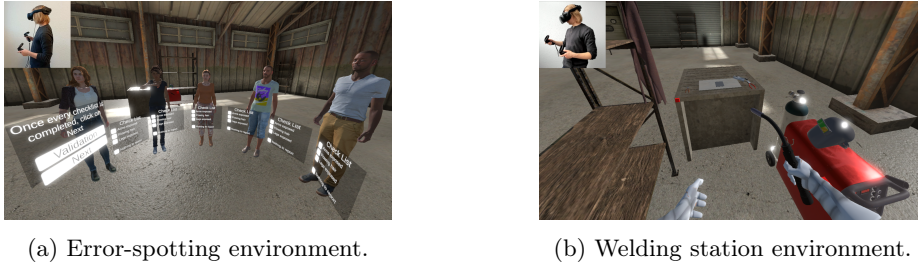


Fig. 2: Environments of the VR welding training application use case. Figures reproduced from Risý et al. 2024 [25] with permission.

application to the training context. The **error-spotting environment** (Figure 2a) helps identify clothing unsuited for safe welding practice and risks posed by loose hair. The **welding station environment** is a functional MIG welding station to teach about safety equipment, welding station setup, and simple welding practice.

The application currently features three scenarios. Domain experts can author new ones to answer different pedagogical objectives.

- **Safety-focused** scenario teaches about safe welding practice while not focusing on the workstation setup or the correctness of the welding gesture. It prevents learners from committing errors.
- **Practice-focused** scenario teaches about welding gesture and workstation preparation. It expects learners to demonstrate safe welding practices without prompting it.
- **Welding-effects** scenario gradually adds the intimidating effects of welding: metal fusion, electric arc, and sparks. It helps explain protective equipment and progressively immerse learners.

In addition, domain experts can access a monitoring interface to author scenarios, choose the scenario for each connected learner, and provide immediate feedback on learners' progression. It contains an accessible authoring interface to author pedagogical scenarios (Section 4.5). Then, the domain expert can decide the scenario to play for each learner connected to the monitoring interface. Finally, the domain expert has access to the progression toward the pedagogical objectives (Section 4.3) of each learner, receives warnings if an error scenario is triggered (Section 4.4), and are notified if a learner asks for help.

3.2 Implementation

The application was developed using Unity and Unity plug-in Xareus¹. Xareus is an enriched Petri net-based scenario engine [5,11] with a graphical scenario authoring tool. SAMPO was implemented in C#, using classes for its specifications and extending Xareus' sensors/effectors logic.

¹ <https://xareus.insa-rennes.fr/>

4 Scenario Authoring using SAMPO

In this section, we start by giving overviews of SAMPO pedagogical principles and the general workflow for the authoring process of the domain expert. Then, we detail each phase of the authoring process.

4.1 SAMPO Pedagogical Principles

The Scenario Authoring Model with Pedagogical Objectives (SAMPO) aims to involve domain experts as direct authors of the scenarios and behavior of their VRET (Figure 1). It uses Pedagogical Specifications written by domain experts as comprehensible building blocks for the application’s educational scenarios. While most scenario models focus on a singular scenario, SAMPO modular approach enables the coexistence of different Pedagogical Scenarios in the same application. Thus, fostering polyvalence and reusability for VRETs.

SAMPO scenarios use an assessment-based approach [26], where progression depends on learners demonstrating skills and behaviors described by the Pedagogical Specifications. These specifications are authored using the Constructive Alignment learning theory [3] and express domain experts’ pedagogical objectives as observable criteria. Thus, the VRET always behaves to guide learners toward the pedagogical objectives, while making the distinction between learner progress and pedagogical decisions. A domain expert represents these decisions by writing Pedagogical Scenarios. They enable SAMPO to change the learning experience depending on learners and teaching objectives. Finally, SAMPO includes a Monitoring component to support domain experts’ involvement during the training session. It provides feedback on the learner’s progression toward the pedagogical objectives and alerts the domain expert of errors made. In addition, it provides the means to interact with the VRET outside of scenario execution.

A learning scenario defined in SAMPO is a combination of three types of scenarios (Figure 3):

- **Reference Scenario:** Expected standard of what learners should be able to do if the pedagogical objectives are reached.
- **Error Scenarios:** Errors cases and learner difficulties (time, accuracy, hesitations) that need to be monitored and can entail pedagogical intervention.
- **Pedagogical Scenarios:** Represent pedagogical decisions by adapting the learning experience. Provide pedagogical guidance, handle error scenarios, and order learning activities.

Using the welding application use case (Section 3), the reference scenario implements every assessment observing the application of safety measures and welding knowledge. Error scenarios represent errors that can be corrected, such as welding with the gas bottle closed, and situations that can’t, such as touching a burning metal plate. Finally, pedagogical scenarios represent the focus of training sessions, for example, one can teach only about safety, deactivation welding practice assessments, guidance, and errors. This structure improves the VRET’s educational capabilities and range of use by giving it the capacity to evolve according to teachers’ and learners’ needs during its life cycle.

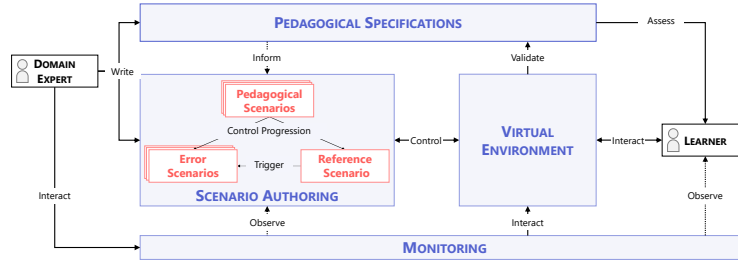


Fig. 3: Main components of SAMPO. Figure adapted from Risy et al. 2024 [25] with permission.

4.2 Authoring process principles

Handing VRET authoring over to domain experts requires giving them a clear perspective on the authoring capabilities at their disposition. The authoring process can be broken into three categories from the domain expert’s perspective: “Specification Authoring”, “Scenario Design”, and “Pedagogical Scenario Authoring” (Figure 4). While each category relies on elements from the previous one, this does not prevent adopting an iterative approach by adding relevant elements when needed. In fact, the domain experts we consulted naturally used this approach when discussing authoring.

The model allows domain experts to instantiate most components, and be fully autonomous in authoring Pedagogical Scenarios. The specifications we propose seek to foster domain expert autonomy while being generic enough to design VRETs tailored to domain experts’ needs and pedagogical approaches. Thus, detailed implementation aspects are out of the scope of this paper to avoid unnecessary constraints on the VRET. Such implementation could be conducted by a domain expert experienced in VR development, a VR expert, or automatic implementation.

The Specification Authoring phase ensures the application can fulfill the domain experts’ pedagogical objectives. Domain experts instantiate Pedagogical Specifications used by scenarios, directly in the VRET. These specifications orient the design process and allow clear communication in the case of collaborative design. In addition, Assessments created in this phase are the building blocks used by the Reference Scenario to measure the learner’s advancement and Pedagogical Guidance needs.

The Scenario Design phase implements the learning reference and the pedagogical content to help achieve it. Domain experts define expected events and behaviors as well as typical Error Scenarios. Then, they specify a range of error handling, adaptive logic, and Pedagogical Guidance available in the Pedagogical Scenarios Authoring phase.

The Pedagogical Scenario Authoring phase results in scenarios created with different educational objectives and approaches. Domain experts define which elements from “Scenario Design” are used by the Pedagogical Scenario, the order

of Learning Activities, and the conditions to proceed from one activity to the next. Finally, domain experts can use previously defined elements to get enriched feedback on the learner’s progression through the Monitoring Component (Figure 3). While “Specification Authoring” and “Scenario Design” phases are likely to happen in a fixed period, this continuous phase allows iteration and evolution of the Pedagogical Scenarios over time.

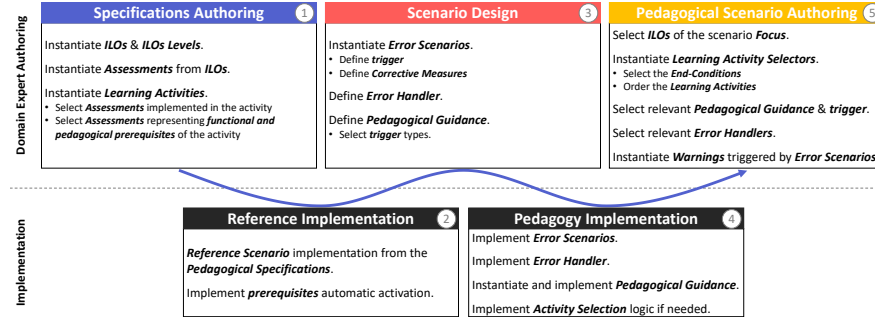


Fig. 4: Description of the authoring process with SAMPO

4.3 Specifications Authoring

Specification Authoring allows the domain expert to embed pedagogical requirements directly and explicitly in the VRET. The first step is to describe these specifications (Figure 5a) using a familiar yet VR-compatible vocabulary, derived from the Constructive Alignment learning theory (Figure 5b). Then, linking these specifications to the virtual environment makes them directly usable by VRET’s scenarios. During this authoring phase the domain expert specifies:

1. **Intended Learning Outcomes (ILOs):** Observable description of pedagogical objectives and expected level of proficiency for a given scenario.
2. **Assessments:** Implementation of observation metrics required to measure the learner’s progression toward the associated ILO. Assessments are used to form objective-based scenarios and condition the pedagogical logic.
3. **Learning Activities:** Learning context that enables learners to achieve pedagogical objectives.
4. **Prerequisites:** Educational and functional requirements of a Learning Activity.

ILOs. Intended Learning Outcomes are defined as “*statements, written from the student’s perspective, indicating the level of understanding and performance they are expected to achieve as a result of engaging in the teaching and learning experience*” [4]. In essence, they provide reliable and observable criteria that can

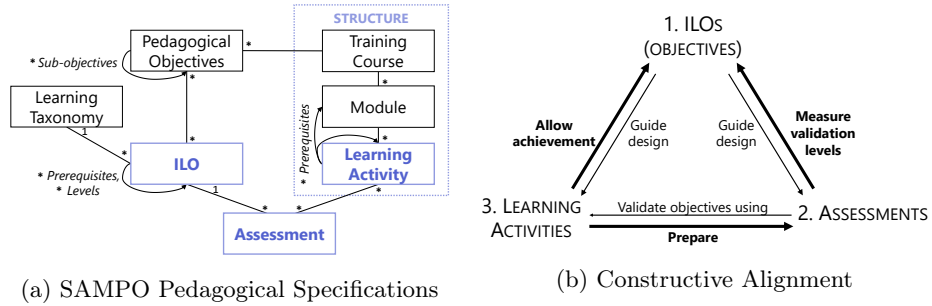


Fig. 5: SAMPO pedagogical specifications based on Constructive Alignment. Figures reproduced from Risy et al. 2024 [25] with permission.

be implemented in an automated training environment to measure the learner’s progress toward the expected level of proficiency. The domain expert instantiates ILOs and writes their content using natural language.

An ILO can be further subdivided into several levels of proficiency. The levels are associated with a learning taxonomy, such as Bloom’s revised taxonomy [1], to qualify the cognitive task they represent. Table 1 illustrates an ILO on welding practice, divided into three levels of competence.

Assessments. The domain expert instantiates Assessments to validate an ILO or ILO Level. By observing the learner’s progression toward pedagogical objectives, Assessments can be used to qualify learning. Assessments naturally derive from their ILO’s description. They interface the Virtual Environment with scenarios, and thus, are an essential part of scenario logic. For example, Table 1 illustrates Assessments implemented in a welding application to validate an ILO. The domain expert may decide that a pedagogical response should be triggered if the validation of an Assessment is lower than a specified threshold.

Learning Activity. The domain expert writes Learning Activities to provide educational contexts where learners can achieve pedagogical objectives. Thus, Learning Activities are the smallest scenario unit a learner can complete. Each activity is linked to a subset of the ILOs representing its objectives and is validated by Assessments of these ILOs. For example, in the welding application, Table 1’s ILOs and Assessments are implemented in an activity describing basic welding practice with a single metal plate. Alongside this activity, other Learning Activities provide context for learning about welding station setup and protective equipment. The Learning Activity segmentation of scenarios allows domain experts to easily enable, disable, and organize scenarios’ sections without impacting the others.

Prerequisites. Prerequisites represent states of the virtual environment that should or need to be reached before the beginning of a Learning Activity. Func-

Table 1: ILO and associated Assessment example. Basic welding practice for a welding training application.

Basic welding practice		
Time: After preparation of the welding station and application of safety measures.		
	ILO	Assessments
Level 1 Remember	The learner is able to: <ul style="list-style-type: none"> - Move the welding torch in a straight line. - Maintain constant and appropriate <i>speed</i>, <i>height</i>, and <i>angle</i>. 	Weld linearity measurement. Compare gesture parameters to the standard.
Level 2 Analyze	The learner is able to: <ul style="list-style-type: none"> - Correct the welding parameters during practice if they deviate from the standard. 	Observe if deviations from the standard decrease in the same welding practice.
Level 3 Evaluate	The learner is able to: <ul style="list-style-type: none"> - Evaluate the weld quality visually after practice. - Correct their next practice using the identified errors. 	Improvement of weld quality scoring. Relies on lower-level Assessments.

tional prerequisites are mandatory domain-specific conditions required for starting an activity. Pedagogical prerequisites represent states that preferably should be reached by the learner before the Learning Activity takes place. Using the example of a “Welding practice” activity, a functional prerequisite would be “*activated welding generator*”, and a pedagogical prerequisite would be “*wearing protective equipment*”. While another Learning Activity “Welding station preparation” allows this state to be reached, the domain expert may want to start the scenario without handling the preparation.

Domain experts can easily add prerequisites to a Learning Activity by indicating any Assessments as functional or pedagogical prerequisites. Prerequisites are not only used to indicate precedence on a sequence of actions but rather that an automation mechanism must be implemented to reach the desired state. In education, domain experts often decide to start “mid-action”, assuming previous steps are known or will be learned later. Thus, handling prerequisites ensures any Learning Activity can be started directly. In addition, prerequisites allow domain experts to decide whether pedagogical prerequisites should be automatically handled if not previously done by the learner.

4.4 Scenarios Design

The “Scenario Design” phase implements the Reference Scenario, the Error Scenarios, and prepares the educational content for “Pedagogical Scenarios Authoring”. The Reference Scenario is the scenario that considers a theoretical learner who validates the Assessments from every ILOs in every Learning Activity. In essence, implementing the Reference Scenario consists of implementing the content described in the Specification Authoring phase (Section 4.3) and does not require any further action from the domain expert. From this base, the domain

expert authors an array of Pedagogical Guidance to help learners attain the Reference Scenario, and Error Scenarios to represent deviations from it.

Error Scenarios. Error Scenarios represent and monitor typical errors that may have, either or both, consequences on the environment and corrective measures. In SAMPO, the definition of an error includes any behaviors that demonstrate the non-mastery of an ILO. This also encompasses learner difficulties, such as hesitation, or taking too long while not committing any mistake. The Domain Expert decides which events constitute an error, and the conditions that trigger the associated Error Scenario. Such conditions can be defined in the Virtual Environment or rely on Pedagogical Specifications. For example, an Assessment lower than a threshold or failing to meet the prerequisite of a Learning Activity may trigger an Error Scenario.

Declaring an Error Scenario is used to notify Pedagogical Scenarios and Monitoring that an eventual pedagogical action is required. This action is manifested as an Error Handler to represent consequences, if any, and provide help if needed. In addition, Error Scenarios may include potential corrective measures to resume the Reference Scenario. For example, in MIG welding training, the Error Scenario “*Gas Bottle is Closed During Welding*” contains a simple corrective step: allowing the learner to stop welding and open the gas bottle.

The purpose of Error Scenarios is not to cover every erroneous behavior. However, remaining deviations from the reference can be caught by non-validated Assessments, and still be associated with a Pedagogical Guidance.

Error Handlers. Error Handlers represent the consequences of an error, and may trigger pedagogical guidance. In essence, they are short scenarios used by the Pedagogical Scenario to respond to the triggering of an Error Scenario. Error consequences often differ between an ecological situation and an educational context. Thus, the same Error Scenario can have multiple handlers. For example, the “*Gas Bottle is Closed During Welding*” Error Scenario from the welding application can be handled in several ways depending on the Pedagogical Scenario. Welding could be blocked while corrective measures have not been applied. Alternatively, the ecological consequences could be represented, namely increasing spark production and degrading weld quality. In addition, guidance explaining the error may be provided in either case.

Unless specified by the domain expert, the Pedagogical Scenario uses “*do nothing*” as the handler for Error Scenarios.

Pedagogical Guidance. Pedagogical Guidance encompasses every means provided to guide the learning process while not being necessary to validate the Reference Scenario. Authoring Pedagogical Scenarios defines the activation and use of guidance. When creating a new Pedagogical Guidance, the domain expert links it with ILOs or Assessments it is related to. This informs both the guidance’s content and the objectives it helps achieve. For example, to guide

learning about basic welding practice (Table 1), relevant Pedagogical Guidance may take the form of a “ghost welding torch” (Figure 6) moving with correct speed, height, and angle, to demonstrate the expected gesture. In addition, the domain expert selects the guidance trigger types to specify possible activation available to Pedagogical Scenarios. Four trigger types are distinguished:

- **Reactive:** Triggered by an Assessment value, an Error Scenario, or the activation of another Pedagogical Guidance.
- **Planned:** Triggered at a specified time, independent of Pedagogical Specifications. It can also specify permanently activated guidance.
- **User:** Explicit guidance request by the learner. Foster learner autonomy by providing control over the learning process.
- **Monitoring:** Triggered by another user through the Monitoring interface.

In the “ghost welding torch” example, the choice of a trigger is informed by the Pedagogical Scenario purpose. “Planned” trigger can be used to explain the gesture, “Reactive” trigger to correct learners’ when needed, or “User” trigger to let learners decide if they need the guidance.

Pedagogical Guidance is not restricted to adding elements to the Virtual Environment. Blocking actions and possibilities to avoid unwanted behavior, such as errors, is also an important form of guidance that can be implemented.

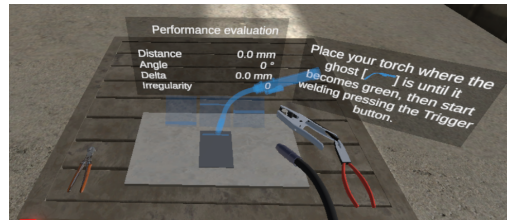


Fig. 6: “Ghost welding torch” Pedagogical Guidance and weld quality feedback. Figure adapted from Risý et al. 2024 [25] with permission.

4.5 Pedagogical Scenarios Authoring

The Pedagogical Authoring phase allows domain experts to compose training sessions tailored to their needs by authoring Pedagogical Scenarios. In essence, Pedagogical Scenarios represent a set of pedagogical decisions to adapt the learning experience. Authoring a Pedagogical Scenario requires that the domain expert defines its “Focus”, a subset of the ILOs used to ensure pedagogical coherence. Then, the domain expert instantiates Learning Activity Selectors to define the activities the learner can go through and their order. Learning Activity Selector allows the construction of linear and multi-linear scenarios. Once the activities are specified, the domain expert can choose the error handler, pedagogical prerequisite handler, Pedagogical Guidance, and trigger used by the Pedagogical

Scenario. Finally, the domain expert can set up Warnings to get enriched feedback on the learner’s progression through the Monitoring Component (Figure 3).

Focus. The core of each Pedagogical Scenario is composed of its “Focus”. This specification contains the relevant subset of ILO levels for the scenario (Figure 7) to guarantee pedagogical coherence. Defining a focus facilitates authoring by automatically filtering available Assessments, Pedagogical Activities, Pedagogical Guidance, and Error Scenarios.

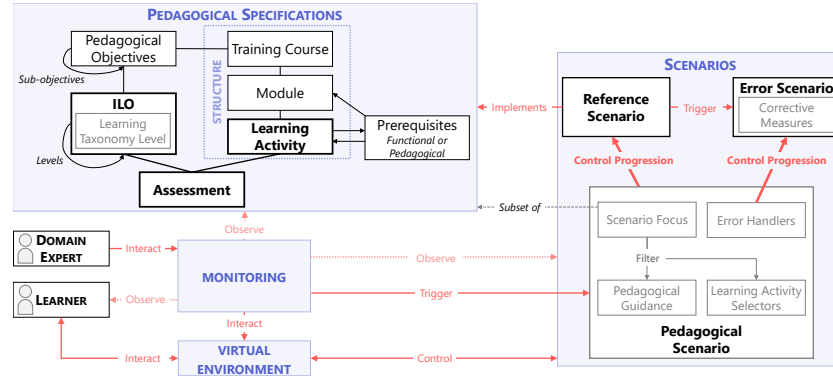


Fig. 7: Detailed view of SAMPO. Figure adapted from Risy et al. 2024 [25] with permission.

Learning Activity Selectors. Pedagogical Scenarios are responsible for structuring the Learning Activities presented to the learner. Consequently, we propose the addition Learning Activity Selector (LAS) class to SAMPO.

In authoring a Pedagogical Scenario, the domain expert adds at least one LAS to each Learning Activity. Each LAS specifies its internal conditions that trigger either the next activity or the end of the scenario. Five types of *end-conditions* are distinguished in a way that maximizes the authoring capability of the domain expert.

- **Assessments:** Specific state defined by a subset of the activity’s Assessments to which are associated thresholds.
- **Monitoring:** Proceeding to another activity is triggered by an external user through the Monitoring interface.
- **Learner selection:** The learner chooses from a set of available activities. The means of selection are application-specific.
- **Random:** Randomly pulls an activity among a set. The domain expert can add weights to the options.

- **External Logic:** Uses custom logic to output the next Learning Activity. For example, this selector could interface a machine-learning model.

We argue for the possibility of authoring multi-linear scenarios to answer the need for powerful educational scenarios. Consequently, multiple LAS can coexist in the same activity. However, adding multiple LAS poses the risk of ambiguous or simultaneous resolution. To solve these situations, we propose LAS need to be ordered by priority to "arbitrate" these cases.

Warnings. Warnings are custom notifications defined by the Domain Expert, sent through the Monitoring interface as the result of a specific Error Scenario being triggered. This system is especially useful in cases where the domain expert cannot monitor a learner the whole time and need to react. For example, if multiple learners are in a scenario at once.

5 Conclusion

This paper presents a methodology for domain experts to become active participants in authoring of VRET scenarios using the SAMPO authoring model. The model also demonstrates how VRETs can be used as effective educational tools that facilitate pedagogical variability. In order to facilitate a more hands-on approach to authoring for domain experts, the SAMPO model has been expanded to include accessible activity prerequisites, pedagogical guidance triggers, and learning activity selectors. The main focus of this paper is on authoring capabilities for teachers and trainers who lack a background in VR development. Therefore, we describe the three-part authoring process of domain experts and the pedagogical specifications used to construct the modular scenarios with SAMPO. We demonstrate how pedagogical coherence is ensured by integrating Constructive Alignment principles as the foundation for the specifications. This enables the Scenario Design phase to implement pedagogical content and error scenarios in a way that elicits pedagogical variability. It is possible to create pedagogical scenarios at any stage of the process, including after the development phase of the VRET.

In future work, we intend to investigate scenario authoring with dynamic adaptation to learners. With the modular scenario architecture of SAMPO, scenario blending, and dynamic scenario changes represent promising ways for exploration. In addition, while domain experts can monitor multiple learners at the same time, learners do not share the same instance of the application. As teaching is also often done collaboratively, we will extend SAMPO to Collaborative Virtual Environments.

Acknowledgments. This work was conducted as part of the AIR project, with the support of state aid managed by the "Agence Nationale de la Recherche" under the "Investissements d'Avenir" program (reference: ANR-21-DMES-0001). The authors thank the pedagogical engineer and INSA Rennes' teachers for taking part in the discussion on the model.

References

1. Anderson, L.W., Krathwohl, D.R.: *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives: Complete Edition*. Addison Wesley Longman, Inc., New York, complete edn. (2001)
2. Ashtari, N., Bunt, A., McGrenere, J., Nebeling, M., Chilana, P.K.: *Creating Augmented and Virtual Reality Applications: Current Practices, Challenges, and Opportunities*. In: *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. pp. 1–13. ACM, Honolulu HI USA (Apr 2020). <https://doi.org/10.1145/3313831.3376722>
3. Biggs, J.: *Teaching for Quality Learning at University: What the Student Does*. SRHE and Open University Press Imprint, Society for Research into Higher Education (1999)
4. Biggs, J.B., Tang, C.S.k.: *Teaching for Quality Learning at University: What the Student Does*. SRHE and Open University Press Imprint, McGraw-Hill, Society for Research into Higher Education & Open University Press, Maidenhead, England New York, NY, 4th edn. (2011)
5. Bouville, R., Gouranton, V., Boggini, T., Nouviale, F., Arnaldi, B.: #FIVE : High-level components for developing collaborative and interactive virtual environments. In: *2015 IEEE 8th Workshop on Software Engineering and Architectures for Real-time Interactive Systems (SEARIS)*. pp. 33–40. IEEE, Arles, France (Mar 2015). <https://doi.org/10.1109/SEARIS.2015.7854099>
6. Bowman, D.A., Hodges, L.F., Allison, D., Wineman, J.: *The Educational Value of an Information-Rich Virtual Environment*. *Presence: Teleoperators & Virtual Environments* **8**(3), 317–331 (Jun 1999). <https://doi.org/10.1162/105474699566251>
7. Buche, C., Bossard, C., Querrec, R., Chevaillier, P.: PEGASE: A Generic and Adaptable Intelligent System for Virtual Reality Learning Environments. *International Journal of Virtual Reality* **9**(2), 73–85 (Jan 2010). <https://doi.org/10.20870/IJVR.2010.9.2.2772>
8. Buche, C., Querrec, R., de Loor, P., Chevaillier, P.: MASCARET : A pedagogical multi-agent system for virtual environment for training. *International Journal of Distance Education Technologies* **2**, 41–61 (2004)
9. Cassola, F., Mendes, D., Pinto, M., Morgado, L., Costa, S., Anjos, L., Marques, D., Rosa, F., Maia, A., Tavares, H., Coelho, A., Paredes, H.: *Design and Evaluation of a Choreography-Based Virtual Reality Authoring Tool for Experiential Learning in Industrial Training*. *IEEE Trans. Learning Technol.* **15**(5), 526–539 (Oct 2022). <https://doi.org/10.1109/TLT.2022.3157065>
10. Claude, G., Gouranton, V., Arnaldi, B.: *Roles in Collaborative Virtual Environments for Training*. In: *Proceedings of International Conference on Artificial Reality and Telexistence Eurographics Symposium on Virtual Environments*. p. 1 (2015)
11. Claude, G., Gouranton, V., Bouville Berthelot, R., Arnaldi, B.: *Short Paper: #SEVEN, a Sensor Effector Based Scenarios Model for Driving Collaborative Virtual Environment*. In: Nojima, T., Reiners, D., Staadt, O. (eds.) *ICAT-EGVE, International Conference on Artificial Reality and Telexistence, Eurographics Symposium on Virtual Environments*. pp. 1–4. Bremen, Germany (Dec 2014)
12. Dalgarno, B., Lee, M.J.W.: *What are the learning affordances of 3-D virtual environments?* *British Journal of Educational Technology* **41**(1), 10–32 (2010). <https://doi.org/10.1111/j.1467-8535.2009.01038.x>

13. Garzón, J., Kinshuk, Baldiris, S., Gutiérrez, J., Pavón, J.: How do pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and research synthesis. *Educational Research Review* **31**, 100334 (Nov 2020). <https://doi.org/10.1016/j.edurev.2020.100334>
14. Gerbaud, S., Mollet, N., Ganier, F., Arnaldi, B., Tisseau, J.: GVT: A platform to create virtual environments for procedural training. In: 2008 IEEE Virtual Reality Conference. pp. 225–232. IEEE, Reno, NV, USA (Mar 2008). <https://doi.org/10.1109/VR.2008.4480778>
15. Horst, R., Naraghi-Taghi-Off, R., Rau, L., Doerner, R.: Authoring With Virtual Reality Nuggets—Lessons Learned. *Front. Virtual Real.* **3**, 840729 (Feb 2022). <https://doi.org/10.3389/frvir.2022.840729>
16. Johnson, W.L., Rickel, J.: Steve: An animated pedagogical agent for procedural training in virtual environments. *SIGART Bull.* **8**(1-4), 16–21 (Dec 1997). <https://doi.org/10.1145/272874.272877>
17. Kleinermann, F., Troyer, O.D., Mansouri, H., Romero, R., Pellens, B., Bille, W.: Designing Semantic Virtual Reality Applications. In: *Proceedings of the 2nd INTUITION International Workshop*, Senlis, France. vol. 61 (2005)
18. Koper, R., Olivier, B., Anderson, T.A.: *IMS Learning Design Specification (version 1.0)* (2003)
19. Lanquepin, V., Carpentier, K., Lourdeaux, D., Lhomme, M., Barot, C., Amokrane, K.: HUMANS: A HUMAN Models based Artificial eNvironments software platform. In: *Proceedings of the Virtual Reality International Conference: Laval Virtual*. pp. 1–8. ACM, Laval France (Mar 2013). <https://doi.org/10.1145/2466816.2466826>
20. Marion, N., Querrec, R., Chevaillier, P.: Integrating Knowledge from Virtual Reality Environments to Learning Scenario Models - A Meta-modeling Approach. In: *Proceedings of the First International Conference on Computer Supported Education*. vol. 1, pp. 253–258. SciTePress - Science and Technology Publications, Lisboa, Portugal (Jan 2009). <https://doi.org/10.5220/0001976102530258>
21. Mikropoulos, T.A., Natsis, A.: Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education* **56**(3), 769–780 (Apr 2011). <https://doi.org/10.1016/j.compedu.2010.10.020>
22. Piaget, J.: *The Psychology of Intelligence*. Routledge, New York (1950)
23. Porteous, J., Cavazza, M., Charles, F.: Applying planning to interactive storytelling: Narrative control using state constraints. *ACM Trans. Intell. Syst. Technol.* **1**(2), 1–21 (Nov 2010). <https://doi.org/10.1145/1869397.1869399>
24. Radianti, J., Majchrzak, T.A., Fromm, J., Wohlgenannt, I.: A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education* **147**, 103778 (Apr 2020). <https://doi.org/10.1016/j.compedu.2019.103778>
25. Risý, M., Gouranton, V., Arnaldi, B.: Handing Pedagogical Scenarios Back over to Domain Experts: A Scenario Authoring Model for VR with Pedagogical Objectives. In: *Proceedings of the 19th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications*. pp. 103–114. SCITEPRESS - Science and Technology Publications, Rome, Italy (2024). <https://doi.org/10.5220/0012397800003660>
26. Udeozor, C., Chan, P., Russo Abegão, F., Glassey, J.: Game-based assessment framework for virtual reality, augmented reality and digital game-based learning. *International Journal of Educational Technology in Higher Education* **20**(1), 36 (Jun 2023). <https://doi.org/10.1186/s41239-023-00405-6>