Assessment and Tracking of Learning Activities on a Remote Computer Networking Laboratory Using the Inven!RA Architecture

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Assessment and tracking of activities in non-traditional contexts, such as immersive environments, is a complex and time-consuming process for instructors. This limits the widespread adoption of immersive environments, since the consequences of those constraints are lack of awareness for orchestration of learning, and lack of elements for assessment. The Inven!RA architecture proposes tackling this problem by collecting status and outcome analytics from multiple immersive activities into a single learning plan, where they are mapped to learning objectives. This enables the creation of learning dashboards for instructors and students, to support their awareness and assessment, enabling learning orchestration and self-regulation of learning. We present an implementation of the Inven!RA architecture in a platform linked to a remote computer networking laboratory, exemplifying how the architecture can achieve its purported goals.

Additional Keywords and Phrases: remote laboratory, Interactive learning environments

1 INTRODUCTION

The tremendous current challenge of instructors in the context of using extended reality learning activities lies in the diminished awareness by instructors of learners' context and activities, hindering monitoring, orchestration, feedback, and assessment.

The issue is both about too little and too much information for teacher analysis and feedback. One can have entire video logs paired with biosensors for each student, overwhelming the ability to extract useful information; or have information on outcomes only, lacking status and process information, missing connections between extended reality learning activities and the overall learning goals within a learning plan. As a solution to this issue, the Inven!RA architecture approach is based on providing instructors with decision-support dashboards via a broker pattern architecture. The concept of Inven!RA is that providers of learning activities (in extended reality or elsewhere) register on the decision-making platform the analytics their activities can provide [1;7]. Subsequently, learning designers can assemble a learning plan, matching analytics from the activities of multiple providers to the overall learning objectives. Instructors can then deploy those learning plans, called Inventive Activity Plans (IAP) with their specific classes of students or trainees, and track the individual progress regarding the learning objectives.

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The range of available activities for inclusion in IAPs is still limited, and examples demonstrating the architecture operation are therefore scarce [7]. So there is a need to provide more diverse implementations, to identify potentially missing requirements, and ascertain the feasibility and robustness of the Inven!RA architecture. In this paper, we contribute to clarify the operation of the Inven!RA architecture, by demonstrating how it was employed in the context of a remote computer networking laboratory, from the analysis of its learning objectives, through collection of analytics, up to dashboard visualization.

2 THE INVEN!RA ARCHITECTURE

This Inven!RA architecture (pronounced [ɪn-vehn-i-rɑ]) [7], represents "a means for Inventive agency amidst reticular ecosystems of atopic habitats within which knowledge emerges" [1]. It enables the implementation of educational orchestration platforms (e.g., dashboards) that acknowledge the occurrence of inventive agency within those rich educational habitats [2]. Thus, it enables collecting information about the learning activities, regardless of their actual internal technical implementation, i.e., a learning plan can combine activities from multiple third parties. Subsequently, instructors and students can check their progress and status towards the learning objectives defined in the learning plan. That enables them to orchestrate the pedagogical intervention (instructors) and self-regulation of learning (students). This architecture presents itself as a pedagogical framework to enable digital transformation in education by aggregating teaching and learning in hybrid and multimodal contexts [3].

The origins of Inven!RA lie in the BEACONING project, which focused on game-based learning, and developed the concept of a learning plan associating gaming analytics with overall learning objectives. The BEACONING workflow required an underlying game plot and game engine into which various minigames providing analytics could be inserted by the learning designer. Thus, the BEACONING learning plans were game plots with associated learning objectives, linked to other sub-activities that enabled monitoring of analytics [4].

Inven!RA takes the BEACONING concept further, by doing away with the requirement of an underlying game plot and engine. It sees each activity as an independent source of learning analytics, provided by third-party Activities Providers (AP). APs register their activities with a platform implementing the Inven!RA architecture, by listing the analytics they collect, and the range of Web services they provide, which enable the Inven!RA platform to configure and deploy the activity, as well as request the collected analytics in the AP for that activity. Inven!RA acts as a broker between the Learning Management System (used by instructors and students) and the APs, associating the analytics with the learning objectives in the plan of activities, which is called an Inventive Activities Plan (IAP).

The current Inven!RA prototype platform was developed in Node.js + moleculer in a React.js framework, communicating with a MongoDB database [1].

The next subsections provide instructions on how to insert figures, tables, and equations in your document.

3 MAPPING USING THE TRIADIC CERTIFICATION MODEL FOR ASSESSMENT AND TRACKING OF LEARNING

The triadic certification model (TCM) is an approach for assessment and certification of learning on immersive activities. TCM incorporates assessment design in the overall learning design process, for activities in a learning/training context [5]. Based on an operative hierarchy of training scenarios, activities, and assignments, the four steps of the TCM help develop the assessment of skill training and combine it with clear and measurable learning objectives within an expected learning configuration. This TCM provides multi-dimensional learning mapping on three axes: expected skills (learning objectives), mechanics to use (tasks), and actual performed activities.

The main objective of the TCM is to incorporate the certification process into the very development of the immersive environment (ideation, design, and implementation), and through the steps that will decisively influence the environment design with the elements necessary for learning certification. This method is not restricted to a specific environment or style, it maps the evolution of the skills acquisition throughout the learning/training activities, framed within a proficiency-level profile, indicative of the situation/state of learning. Certification can be provided upon achieving a specific level of defined competency level.

The first TCM step is the analysis/diagnosis of the training context, with the instructor as content and context expert. In this stage, the training needs/requirements are defined, including the competencies that should result from the training, for certification towards learning objectives. The second step is the mapping by the instructor of the educational competencies that fit the tasks and activities defined in the previous step. This stage results in the definition of the basic skills of each profile of the target groups that will be acquired through training. The third step is the choice of the immersive environment affordances or serious game genre that best fits the basic skills profile defined earlier. In the current case of a remote laboratory, addressed in this paper, this step was a high-level analysis of the mechanics/tasks in operational environment, where one can determine the preferred choice of tasks for acquiring certain skills. Finally, the fourth and last step yields a specific triadic certification model for the case. This depends on the analytics of learner performance within established mechanics and challenges.

The TCM concept intends to standardize environment design for skill acquisition, providing a balance between three components: identified skills and competencies (basic skills), mechanics and challenges based on the environment affordances (mechanics/tasks), and training levels (actual performance). With this authentic certification method, one defines, certifies and validates design contributions of learning objectives and ensures that the planned actions in the environment deliver authentic learning outcomes.

The combination of three learning dimensions in a single visualization/element for the instructor presents itself as a double solution to the issues of tracking the progress of activities and individual assessment of acquired skills. Although initially developed for serious games, this model was subsequently applied to non-game learning contexts. The evolution of the skills acquired throughout the training levels will frame within a proficiency-level profile, indicative of the situation/state of the learning. The profiles distribution by skill throughout training sessions represents each profile's learning through progression in a single or a combination of several mechanics/tasks. This distribution has a greater analytical and organizational complexity when several tasks benefit the progression of competency learning.

The rationale behind the progression implemented at the various levels of training is that each subsequent level integrates the results of the previous level into a logic of accumulation in proficiency profiles. Despite this progressive and cumulative nature, this does not mean that a specific competence might not depend only on a single mechanic or even that a single level of training might combine several mechanics. So, the training levels have dual understood globally rather than individually. This essential commitment to the configuration of the method arises insofar as the learning outcomes result from the mobilization and combination of the mechanics applicable to competence.

In the case of a remote laboratory for learning computer networking, classification through a profile has a dual functionality: first, to categorize all the mechanics/tasks and competency alignments with a learning level, and second, to contextualize the student when performing a training task with a learning result.

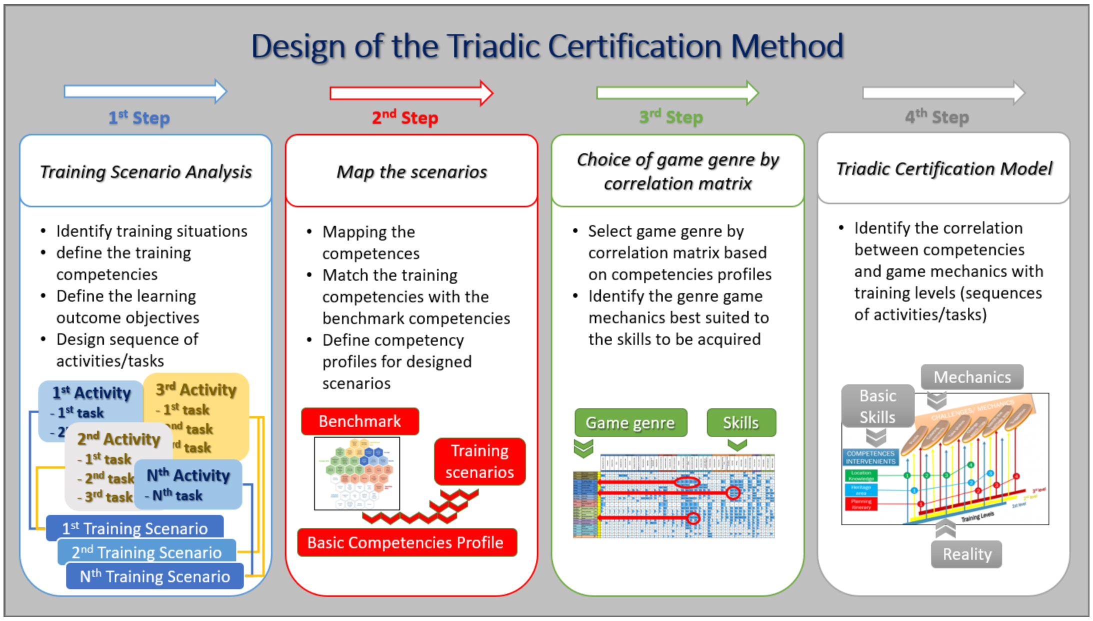

Figure 1: Workflow of the Triadic Certification Method with tools and goals

Each training path incorporates one or more skills that can be learned or trained sequentially. Therefore, this mapping allows instructors to verify the skill evolution along the scale so long as the performance of the mechanics is successful.

Figure 2 shows the mapping of three axes: the expected skills (learning objectives), the mechanics to be used (tasks), and finally, the actual performance (activities).

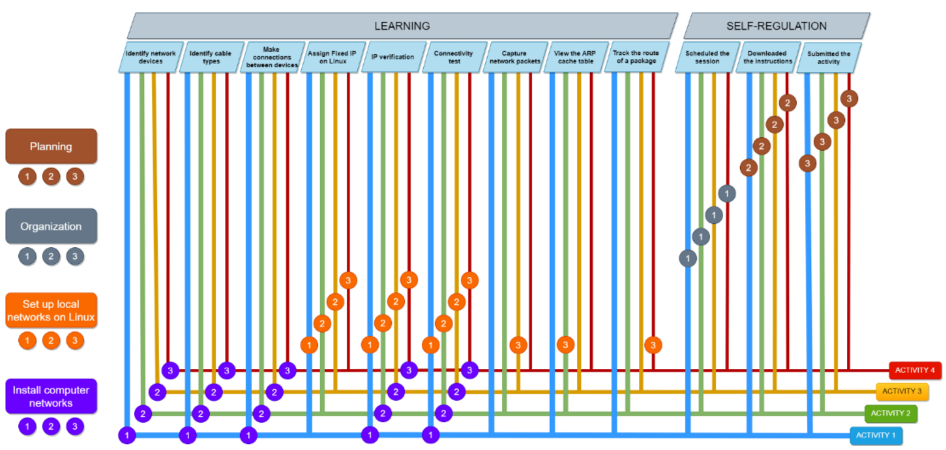

Figure 2: Mapping of the training elements (paths) to competence levels acquired through the tasks in the learning objectives

With this structure, we frame the learning of competencies within each path, where each student accumulates evidence of their learning when successfully performing tasks through the environment. After training, the learning assessment and certification is achieved by combining successful evidence from the various tasks, creating a profile, and establishing the achieved degree of skill [6].

4 CASE STUDY - REMOTE LABORATORY FOR LEARNING OF COMPUTER NETWORKING

This remote computer networking laboratory aims to enable instructors to provide students with learning activities for development of skills in installation and configuration of computer networks. The remote lab's web interface allows students to configure physical connections of computer networks remotely and run Linux commands remotely on those physical computers to setup the networking operation. The physical connections are established with a robotic arm within the lab that physically connects Ethernet cables to network hardware. When designing the learning plan and its activities, the relevant information for the teacher to track and assess the activities was defined, following the triadic certification model [6].

Table 1 presents the learning map of the laboratory activities, where tasks are divided into various activities to achieve the learning objectives, even if they are carried out independently.

Table 1: The learning objectives corresponding to a set of tasks integrating several activities

Skills (Learning objectives)	Tasks	Activities
Install computer networks	Identify network devices	Activities 1,2,3,4
	Identify cable types	Activities 1,2,3,4
	Make connections between devices	Activities 1,2,3,4
Install computer networks	IP verification ('ifconfig' command)	Activities 1,2,3,4
Set up local networks on Linux	Connectivity test (ping)	Activities 1,2,3,4
Set up local networks on Linux	Assign Fixed IP in Linux	Activities 1,2,3,4
	Capture packets on the network	Activity 3
	View the ARP cache table	Activity 2
	Track the route of a package	Activity 4
Self-regulation (Organization)	Scheduled the session	Activities 1,2,3,4
Self-regulation (Planning)	Downloaded the instructions	Activities 1,2,3,4
	Submitted the activity	Activities 1,2,3,4

Our current approach is that the convergence of these three axes provides a mode of assessment acquiring each competence, based on each task's weight in the general plan of activities. The total of the tasks completed corresponds to a ranking in the acquisition of the competencies. But alternative methods of analysis could be considered, for instance to include qualitative assessment or other criteria.

For this example, we designed four computer networking activities and their analytics, which are associated to the learning plan's objectives in a prototype platform implementing the Inven!RA architecture. The remote lab, in the role of Activity Provider, made these activities available to this Inven!RA platform and registered their collected analytics, and the lab Web services. We configured and deployed these activities in the Inven!RA platform as individual Inventive Activity Plans (IAP) (i.e., each IAP had only a single activity).

For IAP configuration, the activity analytics were mapped into the IAP learning objectives, with each of the quantified analytics contributing to a percentage of completion of the objectives. This parametrization allowed step-by-step data collection of activities (Figure 3).

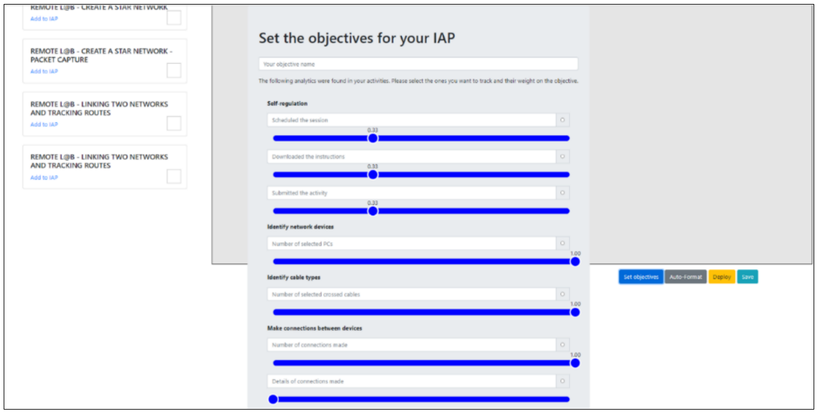

Figure 3: Linking learning analytics with the Inventive Activity Plan's learning objectives, which allows tracking student performance towards those objectives

The instructor can then use the Inven!RA platform to deploy any IAP to a class of students. Upon doing so, the instructor receives activity URLs from Inven!RA and provides them to students via an LMS (in our case, Moodle). These URLs are setup in the LMS to include student identification ("student IDs") in requests when students click on them. Whenever students access these activities in the LMS, they reach the Inven!RA platform, which replaces the LMS student IDs with internal Inven!RA IDs. Students are then automatically redirected to the remote lab, with their identity protected by Inven!RA but still associated with the specific learning plan which their instructor deployed. In the lab, students schedule a remote lab session and eventually carry out the activities. While each student performs the activities, the remote laboratory collects the relevant learning analytics data. Whenever the instructor accesses the Inven!RA platform to check the learning objectives status, the platform requests these analytics from the lab, and updates progress status of the IAP learning objectives. Since Inven!RA can match its IDs to original student IDs, the instructor can track actual student progress in Inven!RA.

The remote laboratory we developed has a digital and a physical component through a robotic arm that establishes the indicated physical connections and, at the same time, interacts with the digital model through the incorporation of other contributions, such as the drag drop environment for configurations, the real-time visualization of the task execution through the robotic arm, and both command line console and visual interface of the equipment for connectivity tests.

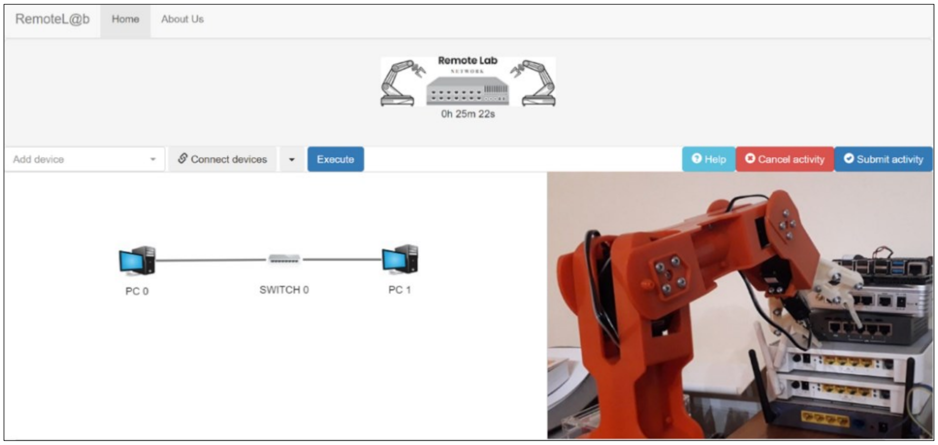

Figure 4: Both visualization parts of remote laboratory, digital and physical components

With the lab integration in the Inven!RA prototype platform, the challenge of tracking the progress of the proposed activities requested to the students by the instructor was achieved. Student use of the lab is restricted to scheduling in temporary slots, allowing for various activities at the student's own pace. Besides the instructor's parameterization/configuration of the analytics, it is now feasible to develop dashboards representing the evolution either in the remote lab with the qualitative data of the tasks' evolution or by consulting the analytics in the Inven!RA platform, as can be seen in figure 5.

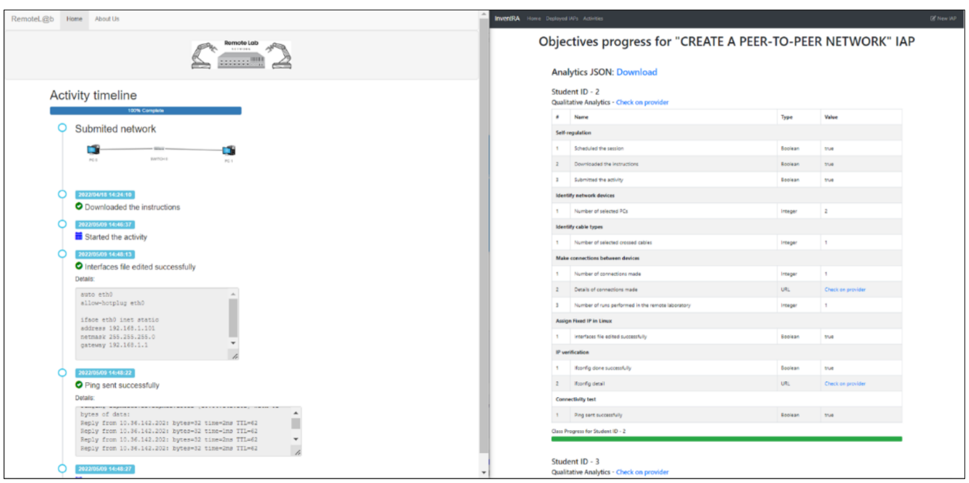

Figure 5: Dashboard with qualitative data and quantitative data about the status of activity 1

5 CONCLUSIONS

The remote laboratory integration with Inven!RA platform supports instructor analysis and orchestration of the activity progress through instructor dashboards. It also enables future development of student-oriented dashboards, to support self-regulated learning. The same approach supports assessment and certification of actual learning towards the learning objectives.

This example implementation clarifies the Inven!RA architecture operation in support of assessment and certification of learning in immersive environments, including Extended Reality, and other contexts, thus furthering the discussion on its feasibility and robustness, and providing pathways towards expansion to other validation contexts.

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