From Worklife Competencies to Educational Virtual Reality Implementations

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***Abstract*—In this paper, we discuss how to implement educational virtual reality (VR) applications based on worklife competencies. VR is a technology increasingly used in education, and VR applications can be used, for example, in workplace learning and vocational education as well as in learning evaluation. We present a development workflow based on the good practices found and applied in multiple development cases. First, we describe the cases and use examples to illustrate competencies and their implementation in educational VR applications, with our observations of relevant good practices. Then, we construct a generalized workflow for developing similar competence-based educational VR applications. Finally, we evaluate the applicability of the workflow and compare it with the typical existing workflows used in software development.**

Keywords—virtual reality, worklife competencies, software development, workflow, Oculus Quest, Unity, 3DVista

I. Introduction

Virtual reality (VR) is a trending technology that is currently used and studied in the field of education [1]–[3]. It is a feasible tool in education, for example, as it provides a way to create digital twins [4] of real-life environments, objects, and people, as well as of person learning [5]. Using VR, it is possible to learn, show, and recognize the competencies required in worklife by performing tasks in which these competencies are applied [6]–[8].

In this paper, we discuss how to implement educational VR applications based on worklife competencies. We focus on vocational education and related competencies relevant to employers and employees. This is because the working environment is changing at an accelerated pace, and new skills and competences are constantly required. The focus of employers is predicted to be shifting from university degrees to competencies relevant to, for example, passing a work-related certification [9]. The following are our research questions:

- RQ1: *What are the good practices in developing worklife competency-based educational VR applications?*
- RQ2: *What type of workflow should be used in developing worklife-based educational VR applications?*

To answer these questions, we use a case-based approach to identify good development practices. Based on these practices, we construct a workflow for developing worklife competencies based on educational VR applications. We also evaluate the applicability of the workflow and compare it with that of the typical existing workflows used in software development.

The rest of this paper is organized as follows. First, we discuss related work in worklife competencies, software development, and VR applications in the field of education. Then, we describe the methodology used, followed by the cases used. This is followed by the results, namely the good practices based on our key observations from the cases and constructed workflow. Finally, in the discussion and conclusions, we evaluate the applicability of the results and their relation to the current software development practices.

II. Related Work

There is considerable related work on worklife competencies and software development. As VR is an increasingly used technology in education, it has also been the focus off late. We summarize the related work on these topics separately to provide the basis for our work.

A. Software Development

Software development is a part of a systems development lifecycle and digitalization, as well as a part of related models, such as those described in [10]–[12]. Traditionally, plan-driven approaches (such as waterfall; e.g., [10]) have been used in software development; however, change-driven approaches (such as Scrum [13]) have gained popularity as agile development has become more mainstream [14], [15]. A hybrid approach is also possible [16]. While both approaches are well known, they must be applied based on the case at hand [17], with varying applications and results [16].

In plan-driven approaches, software development is achieved in consecutive phases, typically requirement analysis, design, build, and changeover (e.g., [10]). The goal is to complete each phase at a time so that the outcomes of the previous phase are used as inputs for the next phase. In change-driven approaches (e.g., [13]), development is iterative, and the tasks of different phases are performed throughout the development. Changes are expected throughout the development, and minimal documentation is used, along with a dedicated source of information that must be constantly available to provide additional information, as required.

B. Worklife Competencies

In education, competencies are most often described as or within a learning taxonomy—such as Bloom's taxonomy [18], which defines three domains of learning: cognitive, affective, and psychomotor. The cognitive domain is the most used and has six levels: 1) knowledge, 2) comprehension, 3) application, 4) analysis, 5) synthesis, and 6) evaluation. The taxonomy was later revised [19] to include only the cognitive domain and its (revised) six levels. An alternative to Bloom's taxonomy, designed as a tool for practitioners and providing a more research-based alternative, is Marzano's new taxonomy [20] focusing on cognitive abilities, which comprises three main systems: the self-system, the metacognitive system, and the cognitive system. In addition to hierarchical taxonomies, there are non-hierarchical taxonomies that broaden the understanding of which competences are relevant for learning [21], [22] by highlighting the aspects of learning that are difficult to measure.

Moreover, frameworks focusing more on qualifications, skills, and competencies exist, such as the European Qualification Framework [23] and European Skills, Competences, Qualifications and Occupations [24], which are general frameworks used across the European Union as baselines for structuring different types of formal and non-formal learning, skills, and competencies. Both frameworks have a strong vocational education focus.

C. VR Applications for Education

VR has already been studied and adopted in various areas, such as computer science, engineering, geography, transportation, and learning hands-on skills in the construction industry [1], [3], [25]. The extent of existing research on applying VR in specific domains varies, but overall, virtual learning should be highly interactive because people learn by doing [2]. VR-based learning can include collaborative interaction with others if it can focus on the environment; however, learning also necessitates individual autonomy. In addition, VR can support learning because it allows students to actively participate [26], and it can increase problem-solving capabilities and improve learning engagement [27]. In addition, VR learning enhances interpersonal communication and fosters a service mindset [25].

Of the areas focusing on vocational competencies, for example, VR is not very widely covered in restaurant work, but some related work exists for completing different work stages [28]. VR is also used in hospitality [29] and tourism [30]. In health care, especially medicine, its use has been studied more extensively, for example, in assessing the food-related emotional responses of patients with eating disorders [31] and in psychotherapy as an alternative to exposure [32]. Medicine is also one of the few areas explicitly connecting worklife competencies with VR implementations to evaluate learning [33]–[36]. As early as 1994, the potential of VR to provide training in laparoscopy was identified [33]. Later, the model was further developed to create an evidence-based curriculum for laparoscopy students, where it was observed that the related tasks can be divided into three levels of difficulty: easy, medium, and difficult [34]. The laparoscopy curriculum was taken a step further by creating descriptions of three types of surgical skills measured using the implemented tasks: safety, technical skill, and dexterity [35]. Recently, VR has been used to assess the competence of emergency medicine students [36].

III. Methodology and Case Descriptions

In this study, we applied a mixed methodology. We used Living Lab approach, where we did a case study. In the case study, we developed two VR implementations based on the specific worklife competencies, one for restaurant work and the other for health care. The case study results were good practices and based on those, we used a constructive method to build the workflow.

A. Living Lab

Living Lab is a user-centered ecosystem that aims to produce innovations, new products, and new services in collaboration with stakeholders [37]. The idea of Living Lab is to solve problems and benefit the economy through practice-based innovation, rapid development, and testing by users [38]. Here, the stakeholders are employers, potential employees, and experts in education.

The potential employees in these cases are immigrants. The employment rate of working-age immigrants is often considerably lower than that of the general population [39], and previous attempts to employ immigrants have not been much successful; thus, new initiatives need to be taken to solve the problem [40]. In addition, we are working in multi-disciplinary environments that require adapting the elements of different approaches to different situations [41], and this is related to service design [42].

B. Case Study and Constructive Method

To identify the good practices for developing VR implementations based on worklife competencies, we applied a case study [43], as we developed two educational VR implementations for different educational areas.

Regarding the building of the workflow, we used a constructive method [44] in which we built on both our related work, the cases, and the relevant work of others discussed in Section II. We synthesized, appended, and connected our ideas and results back to the existing findings.

C. Case Descriptions

The two cases are based on our related work [8] and are summarized in Table I, where their educational area, worklife competence, competence level (on Bloom's original taxonomy's cognitive domain [18]), and related VR implementation are shown. There is a direct connection from worklife competences to the related VR implementations.

The first case is for restaurant work and is related to hygiene competence. Hygiene is an example of a key competence, and there are often requirements that all employees working with food products must follow, so it is seen as important by the employers (represented by restaurant company representatives) as well as experts in restaurant work education (vocational teachers). The VR implementation for the restaurant work [45] involves answering true/false questions presented in a multisensory manner (combination of text, voice, and visual) in the VR restaurant environment by pointing out the right answers.

TABLE I. SUMMARY OF THE TWO CASES

Area	***Competence***	***Competence level (*)***	***VR implementation***
Restaurant Work	Is able to answer simple questions related to hygiene in the restaurant environment	Level 2: Comprehension	Answering true/false (or multiple choice) questions presented in a multisensory manner (combination of text, voice, and visual) in the VR restaurant environment (created with Unity game engine) by pointing out the right answers
Health Care	Is able to handle food products according to hygienic standards in the restaurant environment	Level 1: Understanding	Visually identifying indicators on living situation and state of a person by pointing them out in the VR-assisted living facility environment (created with 3DVista)

(*) Competence levels follow the ones in Bloom's original taxonomy's cognitive domain [18]

The second case is for health care and is related to the competence of evaluating the current living quality and state of a person living in an assisted living facility. This evaluation is a key competence, as employees in health care must be able to assess the living situation and state of a person based on a short visit. Hence, the employers (represented by health care company representatives) as well as experts in health care education (vocational teachers) see this competence as important. The VR implementation for health care [46] is based on visual identification of indicators of a person's living situation and state by pointing them out in a VR-assisted living facility environment.

The VR implementations for both cases were developed for the original Oculus Quest technology [47]. Two different implementation platforms were used: Unity game engine [48] for the restaurant work case and 3DVista [49] for the health care case. The development approach for both implementations exhibited agile characteristics, such as application of ideas from Scrum [13] and rapid application development (RAD) [10].

IV. RESULTS

Based on our cases, we discuss our key observations from a software development viewpoint and summarize them as good practices. We also present a workflow for developing educational VR implementations based on worklife competencies. The workflow guides the application of good practices.

A. Good Practices

Based on our experiences over the period from late 2019 to late 2021, VR is currently a more viable technology for education because affordable standalone VR devices, such as Oculus Quest, have improved in performance, decreased in price, and become easier platforms. In addition, it is possible to develop software for them with widely available game engines, such as Unity. In our cases, with a suitable engine and with enough expertise, even a two-person development team, comprising a designer and a coder, can create a suite of VR implementations within the two-year period.

In both cases, a general target of what the VR implementation should cover originated from discussions with the employers. Namely, it was identified which competencies are important for worklife and feasible to learn or evaluate in VR. Experts in education, as well as the designer and developer, facilitated this discussion. However, for the VR implementation, a more detailed description was required, so the actual tasks or processes in which the competencies are used in actual work situations were drafted by the designer and developer and commented as necessary by the employers so that the contents were validated to be accurate. In addition, the experts in education validated that the competencies were used at the correct level, which matched the general target. Suitable alternatives for these detailed descriptions are use cases, storyboards, or stories [8].

Both cases required environmental modeling, which was achieved using RAD [10]. For example, in the restaurant case, commercial kitchens with their accessories and common operating procedures were studied first. Then, kitchen-sized areas that had boxes as mock-up tables and kitchen utilities were loosely modeled. The models were developed in a 3D modeling program and imported to Unity, where it was seen how everything looked in VR. For example, in normal restaurant kitchens, the layout is based on having tables in the middle as islands and devices on the sides. This is a realistic placement of items, but movement was barely possible, and there was no room for floating question cards, so tables in the middle had to go. The 3D modeling process also showed that it took a fairly long time to model everything. In addition, to obtain some level of interaction, an animated cartoon chef was modeled and added to the implementation.

For the health care case, we shifted first to using images captured using a 360 camera (and later to 360 videos) in environmental modeling to decrease the production time. Each room of the environment was shot in an existing facility, and 360 images were taken from each set-up. This allowed us to have a more realistic environment, and we could shift effort more toward user interaction and other functionalities, such as recording the user's performance to the database for competence evaluation.

As a suitable VR implementation requires a smooth user experience and immersion (e.g., [50]), it was also important to be able to start testing the VR implementations as soon as possible with employers and potential employees. Following RAD [10] and the idea of agile iterations from Scrum [13], the implementations were constantly iterated based on the feedback [8] to improve the experience. In addition, there was a period in iteration when the functionalities of the VR implementations were collected in a single suite, and future proofing of the code base was performed. At this point, we also added guides and improved the usability by, for example, formatting the suite such that, in the beginning, the VR could be set up in a better manner to suit different users' proportions. For example, each person's eyes are different distances apart, which can be compensated by adjusting the VR headset and ensuring that the text can be read clearly. A spacer can also be added to the device to accommodate eyeglass users.

During the development, especially in the early phases, Unity and Oculus development tools progressed rapidly. For example, some interaction-related aspects that worked on earlier computer-based glasses (Oculus Rift) did not work on the standalone Oculus Quest device we used. However, Unity was improved enough so that the standalone device was better supported, and we managed to create a working interaction model. However, there are still some technical considerations, such as the size limit of 2 GB for an application. If a suite (or an individual implementation) exceeds this size, the loading of the content has to be performed adaptively. However, we managed to use better packing algorithms to reduce the final size and keep it within the limit.

Most other problems in the development were either because there was some versioning mismatch between the developer and coder in Unity code packages or just the rapid development of Unity as a platform for VR development, although they did not use cutting-edge versions. This shows how rapidly VR as a platform is currently progressing. Small usability issues have also crept up lately after we acquired newer Oculus Quest 2 devices, as they have slightly different button layouts. Therefore, they do not exactly match the instructions in our current implementations. However, the decision to keep the interaction as simple as possible has helped here, and no functional changes are required to keep the VR implementations operable.

Table II summarizes the good practices we found based on our key observations discussed above. They are categorized into being design-, implementation-, or technology-related. As shown in Table II, we identified eight good practices, of which tree are design-related, three are implementation-related and 2 are technology related.

TABLE II. SUMMARY OF GOOD PRACTICES

	Design
D1	Define a clear general target for the VR implementation from worklife perspective.
D2	Describe in detail the worklife related tasks or process to be implemented in VR.
D3	Validate the contents of the detailed description against the general target before starting the implementation.
	Implementation
I1	Use short iterations and rapid development methods.
I2	Start gathering feedback early and gather it often.
I3	Use continuous integration to avoid versioning mismatches.
	Technology
T1	Evaluate the technological possibilities against the effort they require in development.
T2	Follow technology (such as platform or engine) development continuously.

B. *Workflow*

When building VR implementation (or any other software), the first step is always the design phase. This is where the application scope is determined alongside what the application is meant to do. In this step, it is necessary to have a clear target and its description (D1 and D2 in Table II) so that we avoid feature creep and overly increasing the scope, which almost always results in delays. After we have a good design in mind and the project scope is clear and validated (D3 in Table II), we can start working on the implementation. This is where the actual workflow for the building results starts from a technical perspective.

In our workflow, when starting a new VR implementation, the first step is always to create the project in Unity and set up all VR components required during the development. At this point, there is almost no actual development work being performed, yet this is most likely the first time when a test build is being created, so we can be sure that the empty project works in our test device and that there are no errors with the VR system. This can be seen as the first iteration in the implementation, followed by those in which the actual features of the implementation are built in small steps (I1 in Table II). The features are added and combined in the iterations, and as soon as possible, a release, a working version of the VR implementation that can be tested by the users, is built.

Overall, testing is a major part of the workflow, which relates to both the testing of VR implementation from development and user perspectives (I2 in Table II). This is to find and correct errors in the implementation and to improve the user experience based on the feedback. Errors in the implementation are handled feature-by-feature, and the user feedback is handled release-by-release.

As more complexity is added, development becomes slower. When there are multiple systems in place, all of which communicate with each other, it is easy to make a small change in one system and then have seemingly unrelated parts stop working correctly. This explains, for example, why it is important to use continuous integration (D3 in Table II).

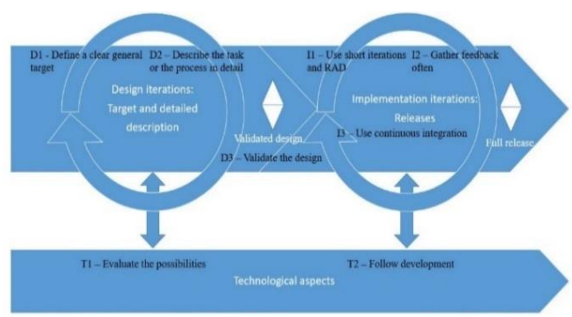

Fig. 1. Workflow for developing VR implementations.

After several releases, fixing the errors, and taking into account the feedback, there will be a release that has the features required to fulfill the described contents and the target of the VR implementation. This is the full release, meaning that the development has been completed and the VR implementation can be published.

Technological aspects are being considered throughout the development. This is because technological possibilities affect the design (T1 in Table II) and because technological development affects the implementation (T2 in Table II).

The workflow is visualized in Fig. 1. It comprises design and implementation iterations. Between them, there is a gate for validated design, meaning that the implementation starts after the design is validated. The design iterations produce versions of the design as long as it passes validation, and the implementation iterations produce releases until the full release is completed and published. Technological aspects are considered in both the design and implementation iterations.

V. Discussion and Conclusions

This paper discusses how to develop VR implementations based on worklife competencies. Regarding RQ1 (*What are the good practices in developing worklife competency-based educational VR applications?*), we identified eight good practices—classified into design- (3), implementation- (3), and technology-related (2) practices, as listed in Table II. The practices guide the development from beginning to full release.

The related existing work shows the benefits of VR, but do not always clearly connect the content with the worklife tasks or competencies. This is why practices D1 and D2 in Table II are essential in the design. Also, the validation in D3 is crucial in order to make sure that the implementation starts with the correct general target. The implementation related practices I1-I3 are in line with the existing work and the change-driven development approach. However, it is worth noticing that the changes should be small in the sense that the general target is not changed frequently, since this will lead to redoing the implementation in a large scale that can be seen as waste of resources. The practices T1 and T2 underline a stable and low effort technology over state-of-the-art and complex ones, again for the benefit of the worklife and based on the experiences gained from the cases.

Regarding RQ2 (*What type of workflow should be used in developing worklife-based educational VR applications?*), we answer it with the workflow presented in Fig. 1. The workflow encompasses good practices in Table II, so following it means applying them as well. The workflow is a combination of plan-driven and change-driven approaches. While a combination, or a hybrid, of the plan-driven and change-driven approaches has been sometimes suggested in the existing work, the details are not that often discussed as thoroughly as they are presented in this paper nor applied in developing VR implementations.

In the workflow in Fig. 1, the plan-driven characteristic is that there is a gate between design and implementation, which can be seen as separate phases that follow each other. The gate is a point of validation, meaning that the implementation does not start in the workflow until the design is completed. In addition, the design is not changed in the implementation, although the resulting VR implementation is constantly improved based on the feedback. The change-driven characteristic of the workflow is that both the design and implementation are performed iteratively. This results in small steps in the development at a time, as well as flexibility. The design can be changed until all stakeholders agree upon it, and the implementation developed in releases can be improved upon until the design and the overall target have been met.

There is also a parallel between the outcomes of the workflow and those of existing software development approaches. The workflow outcomes (Fig. 1), namely competencies, detailed description, release, feedback, and full release, can be mapped to typical software development outcomes, namely requirements, functional design documentation, release, acceptance test report, and full release, respectively. This mapping shows an additional change-driven characteristic of the workflow. Following agile principles, the workflow defines only the most essential documentation along with releases. This does not mean that other documentation is not done, but it is left to be decided if additional documentation of the implementation is required in each development case.

The workflow and the good practices are currently being successfully applied to additional VR implementations, cleaning machine maintenance for cleaning services, and changing the container of tap beverage for restaurant work. This provides additional confidence in that the results presented here are applicable to other worklife competence-based VR implementations as well. Overall, the results are applicable to other software development areas as well. The good practices and the workflow seem to be applicable in general, for example, to software development, where user experience is the major focus. However, this is a topic for further research with applying the results to new cases and refining the workflow if necessary.

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