Conveying Firsthand Experience: The Circuit Parcours Technique for Efficient and Engaging Teaching in Courses about Virtual Reality and Augmented Reality

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Abstract

Providing the opportunity for hands-on experience is crucial when teaching courses about Virtual Reality (VR) and Augmented Reality (AR). However, the workload on the educator's side for providing these opportunities might be prohibitive. In addition, other organizational challenges can arise, for example, demonstrations of VR/AR application in a course might be too time-consuming, especially if the course is attended by many students. We present the Circuit Parcours Technique to meet these challenges. Here, in a well-organized event, stations with VR/AR demonstrations are provided in parallel, and students are enlisted to prepare and conduct the demonstrations. The event is embedded in a four-phase model. In this education paper, the technique is precisely described, examples for its flexible usage in different teaching situations are provided, advantages such as time efficiency are discussed, and lessons learned are shared from our experience with using this method for more than 10 years. Moreover, learning goals are identified that can be achieved with this technique besides gaining personal experience.

CCS Concepts

• ***Social and professional topics*** → ***Computing education;*** • ***Information systems*** → ***Multimedia information systems;*** • ***Human-centered computing*** → ***Mixed / augmented reality;***

1. Introduction

Virtual Reality (VR) and Augmented Reality (AR) are becoming basic technologies in a variety of applications, for example, in industry, medicine, civic engineering, marketing, entertainment, and education. Specific VR and AR hardware is available as consumer products and reasonably priced. Moreover, mainstream smart devices such as smart phones or tablets equipped with cameras or even depth sensors are a suitable platform for VR and AR. Commercial software products for different application domains ranging from medicine to civil engineering are readily available. As a consequence, interest in VR and AR is growing and so is the demand for learning opportunities about these topics. The group of interested learners is not only getting bigger but also more varied. In addition to computer science students, students from other subjects ranging from chemistry to the social sciences are part of the target group for VR and AR courses. But not only students are interested in VR and AR, specialists and decision makers want to learn about VR and AR in order assess the potential of these technologies for their purposes, improve their work processes, or create new business opportunities. Last but not least, educators are becoming interested as VR and AR has the potential to provide innovative and valuable means for teaching and training.

When learning about VR and AR, it is vital that all learners are provided with the opportunity to come into firsthand contact with VR and AR and try out according hardware and software. From our experience, reading text descriptions, watching videos, observing other users, or hearing testimonials from persons who tried VR and AR are not sufficient to meet learning objectives that exceed the basic levels of Bloom's taxonomy [B*56]. This poses a challenge for educators in VR and AR for several reasons. (1) There exists a large variety of hardware used for realizing VR and AR, for example, head-mounted displays (HMDs), stereo projections, haptic feedback devices, controllers, tracking systems and depth sensors, or motion platforms. Moreover, there exists a wide range of set ups such as a 3D powerwall, a CAVE, a virtual workbench, AR with video-see-through on a handheld smart device, AR with direct-see-through employing AR HMDs, or walking in place set ups such as the Virtuix Omni. Ideally, students are provided the opportunity to get firsthand experience across this whole variety. However, this is laborious and time consuming. (2) Some VR and AR devices are still expensive and not available in a large number. This results in lengthy sessions if only one student can have a VR/AR experience at one time and raises the questions what the other students can do during that time. (3) Especially in HMD-based VR where users might not be able to see their real surroundings, it can be necessary

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to supervise students during the experience, e.g., because of tripping hazards or because students may suffer from cybersickness. This can completely occupy the educator and result in a bottleneck. (4) VR/AR hardware may not be available to students outside course hours. Therefore, it is not possible to plan the VR/AR experience as part of their homework. As a result, a significant amount of the course time needs to be invested. (5) Preparing the demonstration of VR/AR hardware with according application examples can take a large amount of time. Moreover, there might be significant effort involved in setting up the VR/AR demonstration before the lesson and putting it away after the lesson. This time burden associated with VR/AR demonstration could force educators to give up on the idea of integrating VR/AR demonstrations in their course.

In this paper, we present best practice how to meet these challenges and describe a technique that we developed for our teaching. This technique is inspired from circuit training in sports and centers around the idea to build a parcours or "'obstacle course"' of VR/AR demonstrations. The contribution of this paper is

- the circuit parcours technique for integrating VR/AR experiences in courses which can serve as a pattern or blueprint for planning courses about VR/AR,
- examples for using the circuit parcours technique in actual learning scenarios,
- a discussion of the advantages and disadvantages of the circuit parcours technique and a report of our experience with it.

The paper is organized as follows. We briefly review related work in the next section. Then, we present the circuit parcours technique and illustrate its usage by providing different examples. Before we conclude, we report and discuss our findings with using this technique.

2. Related Work

Work in literature over the last decades, e.g., [SH96], [HGB10], highlights the importance of hands-on experience in learning in general. On a fundamental level, several learning theories see experience made by students as an indispensable element. Prominent examples are theories based on constructivism which also influences instruction techniques [May09].

In VR and AR, we have the particular case that constructs of perception such as presence [SVDSKVDM01] is at the core of the overall VR and AR methodology. Hence, much effort is invested in employing immersive technologies in VR and AR applications. The experience and the perception associated with using these immersive technologies cannot be conveyed appropriately with just textual or oral descriptions as we cannot put ourselves in the minds of other persons [Dre73]. Overall, we see this bulk of work in the literature about the hands-on experience and learning as supporting our hypothesis that a technique for instruction and organization of courses that enables and ensures the inclusion of immersive experiences for all students can make a valuable contribution.

This dovetails with the observation made in the literature that one significant benefit of using VR and AR in teaching and one of the major reasons for employing these technologies is the opportunity that students are able to have hands-on experiences [CNE*07]. Many case studies such as [RM*13] are described in the literature. Some authors even see the potential to revolutionize teaching in VR and AR because of this [Gad18]. Thus, when hands-on experiences are essential for teaching any subject, these experiences should be especially crucial when the subject is teaching VR and AR itself.

Immersion and experiences are part of VR and AR curricula [FWK*20]. A good overview of the discussion of VR/AR courses for these curricula in the literature can be found in [SD17]. VR and AR are often part of longer courses, in particular, capstone courses [TMPT16]. Not many approaches in literature employ techniques that are suitable for such in-depth courses as well as basic courses or even short introductions to VR and AR that can be taught within one day. The resulting reduced flexibility can pose challenges to integrate VR/AR teaching in existing curricula structures. As a consequence, VR and AR may not be well reflected in the curriculum of many undergraduate institutions although ideas that do not disrupt curricular structures exist for some time [CMD10]. There is still a need for techniques that lower the organizational barriers for including VR and AR in teaching, especially if hands-on experiences with VR/AR are part of the instruction.

Courses about VR and AR development are becoming more popular and varied as it is feasible to use low-cost systems for several years now [AH08]. Now, a more serious obstacle than costs is the creation of content. Here, tools and matching authoring approaches such as VR/AR Nuggets [HD19] have been identified as effective solutions. Nguyen et al. report that VR/AR applications can be developed successfully within courses and students were able to adopt necessary tools [NJD19]. Therefore, we will assume in our work that the prerequisite of existing suitable authoring tools can be met.

Experience with courses that teach VR and AR demonstrate the positive effects of group work [MUH10]. Moreover, many approaches to teach VR/AR are project-based [Sta05] [HHO13] which provides substantial opportunities for group work. Existing research work also shows that VR/AR courses can address learning goals beyond VR and AR technologies and methodologies such as creativity, problem-solving skills, or presentation skills [NHD18]. Thus, a good instruction technique for VR and AR learning should foster group work, project-based learning, and the acquisition of soft skills. Such suitable instruction and organization techniques were and are still open areas of research [Bur04] [SD17].

3. The Circuit Parcours Technique

We assume that we have n students and one teacher in the course. We divide the students in k groups of equal size s (with $s = n/k$). Moreover, we have k stations. At each station, a number of identical VR/AR demonstrations will take place where one student will be able to experience this demonstration and gain firsthand experience at a time. Each station has an according set up of VR/AR hardware and software. The VR/AR demonstrations differ from station to station.

Our technique is illustrated in the diagram in Fig. 1. The parameters we will use in the following are listed in Fig. 2. We distinguish four phases. In phase 1, the outline phase, each group is assigned to one station. The demonstration to be given at each of the k stations is specified and according VR/AR hardware and software is

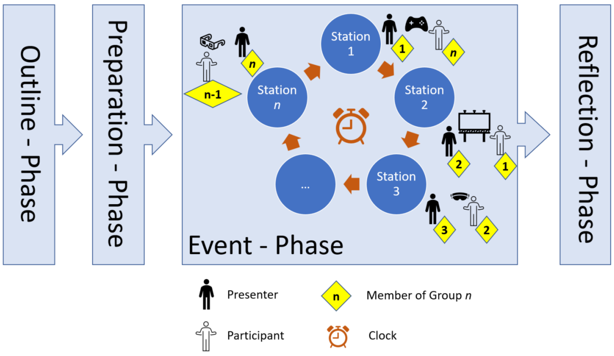

Figure 1: *The four phases of the circuit parcours technique. In the event phase, a snapshot of a demo session is shown - in this example groups of two students are formed and each group member has either the role of a presenter or a participant at the various demo stations each with a different VR/AR demo.*

Variable	Description
T	Circuit partcours duration of one event
e	Number of events for one circuit parcours
E	Overall circuit parcours duration
n	Students
k	Groups / demo sessions in one time slot
s	Group size
t	Time limit per participant per station
g	Guests
N	Total number of demo sessions
t_{setup}	Setup time before an event
b	Number of breaks within one event
t_{break}	Break time per break
t_{end}	Disassebling time after the event

Figure 2: *Overview of variables of the curcuit parcours technique*

selected. The educator either hands a complete specification to the group assigned to the station or provides this group with just some constraints (e.g., the hardware to be used in the demonstration). In the latter case, the educator asks the group to complete the specification. For each demonstration, a fixed amount of time is available. The teacher specifies this number of t minutes and communicates this to all groups. This time t has to be taken into account when specifying the demonstration.

In phase 2, the preparation phase, each group prepares the hardware and software infrastructure for the specified demonstration (e.g., procuring the hardware, configuring the software). They test the VR/AR setup at their station. Moreover, they work out an action plan for conducting a demo session that also takes the timing into account. In the action plan, three roles are distinguished: the presenter, the participant, and the observer. During each demo session, there is one participant present who is actively engaged in the VR/AR experience provided at the station. The role of the presenter is to prepare the next presentation (e.g., to wipe down devices in order to meet hygienic standards or to reset the software), to welcome the participant, to provide some background explanations concerning the demonstration, to guide the participant through the demonstration, to ensure the safety of the participant during the demonstration, and to conduct a debriefing after the demonstration. The role of the observer is to monitor the observance of the action plan, to make notes about observations during the demonstration, and to assist the presenter when necessary. In each demo session, there is one person who takes the role of the presenter. The number of persons who take the role of an observer can vary between 0 and s. In the preparation phase, demo sessions are rehearsed and based on the outcome of the rehearsal the action plan is adapted. The action plan needs to ensure that the time limit of t minutes is obeyed. In the rehearsal, the members of the group assigned to a station take on each role at least once.

In phase 3, the event phase, an additional number of g guests can be invited. The educator can be among these guests who also participate in a demo session at every station. The educator prepares a timetable where all demo sessions are listed. For each demo session the timetable provides the following information: the start time, the name of the participant at each station (either a guest or a member of a group that was not assigned to the station) and the names of the presenter and potential observers (who are all members of the group assigned to the station). There are $N = n \cdot (k-1) + g \cdot k$ demo sessions in total. As there are k demo sessions in a single time slot, N/k time slots of length t minutes need to be planned. The event phase starts with the set up where the demonstration at all stations is prepared and set up. This takes t_{setup} minutes. The educator is in charge of ensuring that the timetable is kept. The educator gives according signals (e.g., using a gong) when a demo session is to start. Each student will visit all stations (except the station the student is assigned to) and experience the according demos in the role of a participant. In the remaining time, the student is at the assigned station and serves either as presenter or observer. In order to mitigate the effect that unforeseen events mess up the schedule in the timetable, a number of b breaks of t_{break} minutes can be planned. The purpose of these breaks is not only relaxation and providing all persons the opportunity for drink, food, or a bathroom break but also synchronization among the stations. If one demo session takes longer, further sessions may be affected as the presenter or the participant may not be available in time for their following demo sessions. That can cause a ripple effect that can be stopped with breaks that work as a time buffer. After the last demo session, the stations are disassembled. This takes t_{end} minutes. Overall, the event takes the time $T = t_{setup} + (N/k) \cdot t + b \cdot t_{break} + t_{end}$. If the duration of T is too long to fit in the teaching schedule, the event phase needs to be split. This adds an additional time $t_{setup} + t_{end}$ for each additional meeting. If e is the number of all events to be held and E is the time needed for all event phases, than $E = T \cdot e$ in case we split the event phase in a way that all e events have the same length. We can calculate E directly as $E = e \cdot t_{setup} + e \cdot (b \cdot t_{break}) + (N/k) \cdot t + e \cdot t_{end}$.

Phase 4, the reflection phase, is added to deepen the experience and reinforce the learning results. Reflections could range from filling in a questionnaire individually to short informal discussions among students about their own experiences and observations to more formal reports and presentations. For instance, students could be asked to perform a qualitative or even quantitative evaluation based on their observations at their station. These results together with the description and discussion of their demonstration protocol, lessons learned when implementing the prototype software, lessons learned when conducting presentations and user tests, and overall observations and conclusions could be assembled in a report or presented to the other groups in a session following the event. The reflection phase is valuable for the educator to evaluate the progress of the students or for grading purposes. Moreover, the educator can gather pieces of information about the students' performance by observing the presentations (especially if the educator serves as a pilot participant or guest), by examining the software created and by evaluating the overall presentation design. As presenters can be observed individually and the group can be asked to detail and rate each team member's contribution, it is feasible to assess each student's individual performance despite relying heavily on group work. In the simplest case, the goal is to provide a firsthand experience of VR/AR and the mere participation of a student trying out a VR/AR presentation is sufficient to ensure that this goal is met.

4. Examples

A first example for employing the circuit parcours technique is an undergraduate course "‘Virtual and Augmented Reality"’ for computer science students in their 4^{th} semester. The course has 15 participants and a workload of 150 hours. The course is taught in a VR/AR lab. There are four hours per week that consist of lecture-based instruction, student presentations, practical work and tutoring. The proportion of these varies over time with an emphasis on instruction at the beginning of the course and a focus on students' practical work at the end. Overall, the ratio of instruction and practical work is roughly 40:60. Moreover, students have daily access to the VR lab where each student has access to a locker where their VR/AR equipment is stored. The students are divided in five teams of equal size. Each team receives some VR/AR hardware and a research question where a user test needs to be conducted in order to evaluate two alternatives. For example, one group receives a VR HMD and is tasked to compare two different techniques for navigation in a VR environment. Another example would be a group who receives a tablet and an AR HMD and is asked to evaluate advantages and disadvantages of direct-see-through and video-see-through. The time for each demo session was set to $t = 20$ minutes. In phase 2, each group needs to develop prototype software that serves as the basis for the user test. Various software such as game development platforms (e.g., Unity), dedicated VR software (e.g., Autodesk VRED), or toolkits (e.g., ARKit) is used so that students do not need to start from scratch. The educator supports the students with regard to prototype development but also provides feedback to the planning of the user test, e.g., by reviewing the questionnaires to be used. The educator provided a schedule, so it was clear who had to be at which station in which role during the event. The main event (phase 3) had to be split in two dates. Two guests were also present. One of the guests was the educator who could also experience each station. Two breaks with $t_{break} = 5$ minutes were planned, t_{setup} was set to 15 minutes, t_{end} was set to 10 minutes. Two stations of the event are depicted in Fig. 3. In summary, each of the two events had seven demo sessions and took 175 minutes. The students organized a third event voluntarily where they invited friends, family and fellow students. In the final phase, each group gave three presentations. The first presentation was about educating the other students in the course about the software they have used for prototyping and the lessons learned using this software. In the second presentation, each group reported the results of the user tests (including a statistical analysis) and discussed them. With the two regular events, each group had conducted 14 user tests (involving the twelve other students who were not in their group plus the two guests), with the additional third event this number was increased to 22 user tests which provides a good amount of data for a meaningful statistical analysis and discussion. The third presentation was about the reflection of the experiences in the course where all groups focused on the experiences they made when trying out the VR and AR equipment at other stations. The 15 weeks of the semester were distributed among the phases as follows: phase 1 took one week, phase 2 took nine weeks, phase 3 took two weeks, phase 4 took three weeks.

Figure 3: *An example of two stations in the circuit parcours.*

The second example for employing the circuit parcours technique is a two-day course for the further education of university teaching staff who have no background in VR or AR but want to assess in how far these technologies can benefit their teaching. The number of participants is 12. In the first phase, groups of two are formed and each group receives a device with VR or AR capabilities (e.g., an iPad, a Oculus Go VR-HMD, a Microsoft Hololens). There is one pre-installed app on each device, for instance Froggipedia (an AR learning app about biology from the Apple App Store), Human Anatomy VR (a VR App available in the Oculus App Store that supports the exploration of the human anatomy), Samsung's BeFearless VR app for training public speaking, or Microsoft's Dynamics 365 AR-based collaboration app for the Microsoft Hololens. For the 60 minutes preparation phase, each group was given the task to become acquainted with the software, read manuals or watch video tutorials, and plan a 10-minutes-long demonstration. The groups are told that in this demo, a short introduction should be provided and the VR app or AR app should be exhibited. Immediately afterwards, phase 3 started with a total of 10 demo sessions at six stations. Overall, this event phase took 120 minutes ($t_{setup} = 0$ minutes plus $10 \cdot t = 10$ minutes plus two breaks with $t_{break} = 5$ minutes plus $t_{end} = 10$ minutes). In total, three hours of the course time were devoted to the demonstration so that participants could get some firsthand experience. In the fourth phase, a group discussion is started where experiences made are reflected and each participant is asked to write down three (or more) ideas in light of the impressions of the demos how VR and AR technologies might improve their teaching.

A third example is an undergraduate course in chemistry in the third semester where students have a laboratory course in which they spend four hours per week in one of the university's laboratories and four hours per week preparing the course at home. Digitalization also became an important topic in chemistry and the educators want that their students get some firsthand experience with virtual laboratories. They want that students are able to assess the value of VR as a tool for preparing laboratory experiments. The 120 students of the course are already divided in six groups of 20 students for the practical lab work and these groups are treated identically in the following. In phase 1, each of these groups is further divided into groups of 3 students each (and one group with only two students) who are assigned to seven stations. Each station has a different topic (e.g., the presentation of some lab equipment or a specific chemical experiment) and has some VR headset (reaching from simple headsets such as Google cardboard to more sophisticated VR HMDs). In the preparation phase, the students work through a video tutorial where they learn to use a dedicated editor for demonstrating laboratory experiments. This editor is based on the concept of VR Nuggets [HD19]. The basic idea of VR Nuggets is that they are standalone, always functioning VR software components to be used for education purposes. The VR Nuggets provide all the complex base functionality for a certain use pattern, e.g., the *show and tell pattern* where a virtual object can be interactively explored in 3D together with labels that provide additional information. If the student group aims to demonstrate a certain lab device, they need to select the according VR Nugget and change its configuration, i.e., substitute the existing dummy virtual object with the specific object from an asset store and place the labels in 3D space accordingly. The VR Nugget software makes sure that the labels are always positioned in the virtual world that they are readable by the students and provides interaction techniques for exploration. VR Nuggets are not meant for creating a whole course in VR but to support the introduction of some VR content in a regular course where VR has a substantial added value. The student groups have two weeks to create the VR content and prepare the demo at their station. In phase 3, the event is conducted. The event takes 120 minutes ($t_{setup} = 10$ minutes, 18 demo sessions with $t = 5$ minutes, $t_{end} = 10$ minutes, two breaks with $t_{break} = 5$ minutes) and is short enough that there is no need for a split. In phase 4, the students are expected to discuss their experiences within the group and write some text about the outcome as part of their usual lab report.

5. Experiences, Evaluation and Discussion

In teaching a VR/AR course for computer scientists in a university (see example 1 in the previous section), we have employed the circuit parcours technique seven times (in the time span from 2009 to 2020). We have never experienced any problem with applying this technique that resulted in a failure. The technique proved itself to be robust and working well. Students particularly appreciated the event like character and the variation in teaching methods. In five out of seven cases, the students voluntarily organized additional events and invited fellow students and friends or family. We take this as a strong indication that students felt motivated and were well engaged. In our universities' quality assurance where all courses are evaluated with a standard questionnaire, our VR/AR course was rated well above average. While this is not necessarily due to the circuit parcours technique, written comments in the evaluation questionnaire (that highlighted the practical and hands-on experiences as valuable or mentioned the event as fun) provide some anecdotal evidence that this approach to organize the course was perceived as positive. There was not a single negative comment referring explicitely to the circuit parcour techique in all seven questionnaires.

One lesson learned was that enough time has to be planned for switching stations (e.g., to cater for cleaning times between two demos in order to adhere to hygienic standards) and breaks that serve as buffers are important in order to prevent that everything is thrown out of sync. It is also valuable to have a big block visible from every station and an audible signal (such as a gong or a ring) that informs everybody that a new session starts. We found it to be beneficial that the educator is not just an observer during the event but a guest at every station participating in each demo. This allows the educator to interact with each group and provide some feedback after the event. Alternatively, the educator can serve as a pilot user for each station during the preparation phase. One of the biggest challenges for the educator is to ensure that each group has roughly the same workload for preparing the demonstration at their station. As all stations are different, suitable tasks have to be identified by the educator that the group is able to accomplish in the time frame of the course. Moreover, these tasks should neither underchallenge nor overwhelm the groups. For this, the educator needs knowledge on the students' competencies. There is a wide spectrum with regard to difficulty in content creation for the demonstration. One the one hand, existing applications can be employed as is. However, they are often a black box for the students and the demo preparation is too effortless. On the other hand, students can create the demonstration from scratch using low-level APIs such as Vulkan and according GPU shaders. Here, the VR nugget approach is particularly interesting as it is in the middle of the spectrum where not many solutions are present. The preparation effort on the educator's side should not be underestimated. Not only need suitable tasks and development environments to be identified but also additional material such as 3D geometry assets need to be provided if this cannot be made part of the students' tasks. Moreover, instruction has to be prepared, e.g., in the form of a text book, video tutorials or lecture. This might differ from station to station. Part of the planning is also the calculation of the times for the events that need to fit the individual time constraints of the course. Finally, the educator has to assess how the circuit parcours pattern can be tailored to fit the constraints of the course or curriculum. It might be even necessary to change the curriculum or the organization of teaching in order to fully exploit the advantages of the presented technique. One particular problem occurs if the number of students is not divisible by the number of stations. A good solution is to have some groups that are slightly bigger than the others and to invite guests during the event to make sure that all stations are fully occupied during each session and that all students can take the role of a participant and the role of a presenter.

From our experience, the circuit parcours technique allows to address more learning goals than providing students with the opportunity not only to hear about but to experience VR/AR hardware and software. (1) The students are trained to be attentive and observe VR/AR users actively. (2) The students switch the roles of presenter and participant and thus improve social skills such as empathy. (3) Students learn about presentations and especially the demonstration of VR/AR applications to third parties. (4) Time management and discipline in carrying out a demo or test protocol can be trained. (5) The technique provides opportunities to be creative and learn how these creations are experienced by others. (6) Fundamentals of user tests can be also learning objectives, e.g., the circuit parcours technique facilitates the recording of test data in a short amount of time that can serve as basis for further analysis. In particular, meaningful statistical analysis requires a minimum amount of test data. This amount can be obtained in the event phase.

Concerning time efficiency, the circuit parcours technique is superior to a linear demonstration of VR/AR applications by the educator alone. While the latter takes at least $n \cdot k \cdot t$ minutes of time for demonstrations, our technique takes less than $1/k^{th}$ of that time. For instance, in example 1 a linear approach would take a demonstration net time of 1,500 minutes (25 hours) compared to 280 minutes. Our technique is a solution for the educator being a bottleneck in demonstrations. On the other hand, additional time needs to be invested by the students for the preparation. However, here groups of students can work in parallel. Moreover, the students can reap benefits from the preparation in addition to the benefits of experiencing the demonstration. The circuit parcours technique also ensures that there is no idle or waiting time for students. They are always active and involved, either as participant, presenter, or observer.

The presented technique does not only mitigate the problem that individual hands on experiences take time. Moreover, the educator is relieved of the tedious task to oversee every demonstration. In addition, the educator is not required to fully plan and prepare the demonstration (install software, create or customize the demonstration, set up the hardware equipment). In a sense, the students take over some work of the educator which provides learning opportunities to them. As a consequence, the significant overall reduction of the educator's workload could mean that the inclusion of individual hands on experiences in a course can become feasible in the first place. In this case, our technique has all the advantages that come with hands on experience as opposed to just hearing or reading about VR/AR experiences. We have not evaluated the extent and scope of these advantages further as they are not specific to our technique but to the provision of individual experiences in VR/AR education in general. Our technique is rather an enabling factor in this situation. For instance, we did not evaluate the added value of firsthand experiences in VR/AR education with an experiment that had a control group. However, this is examined in the literature and our experiences confirm findings that firsthand experiences are crucial for the understanding of VR/AR.

Enlisting students to conduct VR/AR presentations might be seen as inferior to the educator performing this task as the presentation abilities, didactical competencies, or verbal capabilities of the students might not be as well developed compared to the educator. However, the firsthand experiences each student is able to make with VR/AR even with an inexperienced student presenter instead of an experienced educator are valuable. This is especially true if the alternative choice is not between inexperienced student presenter vs. experienced educator but between firsthand experience vs. no firsthand experience because limited resources and other constraints can force the educator to abandon the idea to provide firsthand experiences in VR/AR. Based on enlisting students, the circuit parcours technique can again be seen as enabling factor for firsthand experiences. Moreover, the student presenters conceive and rehearse their presentation within their group during the preparation phase. Here, the group members can provide valuable feedback. The educator can also use the preparation phase to perform some quality assurance of the presentations and user test protocols before the event phase, especially if the educator takes the role of a pilot user. The concrete task to act as presenter can be a good occasion to motivate students to work on their presentation skills and didactical competencies. Hence, the educator should consider providing according learning opportunities (such as instructional videos or even a compact course about relevant soft skills).

An additional advantage of the circuit parcours technique lies in the fact that students not just experience k demonstrations. They invest significantly more time and effort in the one demonstration that they are responsible for. As a result, a good balance can be struck between getting an overview and getting to know one example more in-depth. Moreover, the technique enlists the learners as tutors for their fellow students. This provides opportunities in learning soft skills and can also have motivational aspects that their work is rewarded with supporting and educating others. There may be additional motivational aspects based on the high degree of active involvement, the work in groups, or the event character.

6. Conclusion and Future Work

The circuit parcours technique describes a basic pattern for best practice how hands-on VR and AR demonstrations can be integrated in a course about VR and AR. The major idea is to define several demonstration stations that are used in parallel during a carefully organized event. Moreover, students switch between roles as participants and presenters. Thus, students are not only recipients of the demonstrations but are entrusted with preparing and actively presenting VR and AR applications. This relieves educators from time-consuming tasks that are associated with integrating VR/AR demonstrations in courses. The central event is embedded in a four phase model: outline, preparation, event, and reflection. By comparing time efforts with traditional demonstration approaches, it can be shown that the presented technique is significantly more time efficient. Besides time efficiency and the reduction of the workload of the presenter, the technique has additional potential advantages such as the ability to address several learning goals ranging from several soft skills (time management, presentation skills, etc.) to user testing or VR/AR programming, the increase in student motivation, and the balance between in-depth learning and provision of an overview. As a result, obstacles are mitigated by this technique that could prevent educators to include hands-on demonstration of VR/AR in their courses. Thus, a major advantage is that the technique contributes to providing students the opportunity to experience VR and AR applications themselves instead of just reading, hearing, or seeing a video about them. These experiences are considered to be of key importance when learning about VR and AR. Describing three different application examples of the circuit parcours technique, we showed how flexible the technique can be used in different situations that range from semester-long courses to one-day seminars, from specialist target groups such as computer science students to non-technical specialists, from courses with few participants to courses with a large number of participants. This leads to one direction for future work where further techniques for teaching can be derived from the technique presented. For instance, two courses with a large number of students (who will only take the role of a participant) and with a small number of students (who prepare and conduct the VR/AR demonstrations in an event) can be combined. As a result, a large number of students could gain some hands on experience with VR/AR in a short amount of time while a small number of students can acquire in-depth experience in creating and presenting VR/AR applications, potentially with conducting research, e.g., in usability. If 16 students, for instance, prepare 16 stations with five minute long demonstrations each, 96 students can experience 3 demonstrations each within a time frame of only 90 minutes. Another direction for future work would be to provide a dedicated authoring tool for preparing demonstrations for the circuit parcours technique and an environment for content creation. Here, the VR nugget approach can serve as a promising starting point.

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