A Cross-Disciplinary Course on Virtual Reality

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***Abstract*—This Innovative Practice Work In Progress paper describes the author's efforts to develop a cross-disciplinary undergraduate upper division and graduate level Virtual Reality (VR) course. Virtual Reality is a truly cross-disciplinary field that often involves Artists, Computer Scientists, Engineers, Psychologists, and others working together to build and evaluate computing experiences that immerse users in rich 3D virtual environments. Twenty-six undergraduate and graduate students from Computer Engineering, Computer Science, Education, Engineering Management, Media X, and Psychology completed the author's course in the spring of 2018. The course was arranged into three units: applications, foundations, and evaluation. Throughout the term students worked in cross-disciplinary teams of two to three to build and evaluate a VR application. During the last week of the term students completed a questionnaire designed to assess the success of the author's approach to the course. Results of the questionnaire suggest that while the author was successful in teaching students about the cross-disciplinary nature of VR, more could be done to support students as they learned to collaborate with teammates from other disciplines.**

Keywords—Virtual Reality, cross-disciplinary, education

I. Introduction

Virtual Reality (VR) is an exciting and contemporary topic with applications in areas such as gaming [1], education [2], therapy [3], and training [4]-[5]. VR is a truly cross-disciplinary field that often involves Artists, Computer Scientists, Engineers, Psychologists, and others working together to develop and evaluate immersive computing applications and the hardware that supports these applications. Career opportunities in VR have never been greater. Unfortunately, there exists little in the literature describing VR courses taught in a manner that reflects the highly cross-disciplinary nature of the field. This paper attempts to fill that gap. The next section describes the field of VR as well as a brief history of approaches to teaching the subject. The following section discusses the structure of the author's cross-disciplinary VR course, and then a description of the course evaluation is provided. The paper concludes with a summary of lessons learned and future plans for the VR course.

II. Background

A survey of two popular textbooks [6]-[7] reveals that *interaction* and *immersion* are important elements of VR applications. Interactive computing applications are those that allow users to manipulate the state of the application in one or many ways. Common interactive tasks in VR include navigation throughout 3D virtual environments, and selection and manipulation of virtual objects [6]-[8]. Immersion is a topic that is often less well understood by students. Sherman and Craig [7] describe two types of immersion: mental immersion and physical immersion. Mental immersion refers to the feeling or sense of being in a virtual space when physically located somewhere else. Those in the VR community often use the phrase *sense of presence* to describe this phenomenon. Physical immersion involves the use of special hardware to present a 3D virtual environment to users. Contemporary immersive hardware devices include the Oculus Rift (oculus.com/rift) and HTC Vive (vive.com) and their associated controllers that track user hand movements. One might think of the goal of VR as to present an application to a user through the use of special hardware (physical immersion) to increase the user's sense of presence (mental immersion).

Virtual Reality has been a field of academic research for more than two decades. The first Institute of Electrical and Electronics Engineers (IEEE) Research Frontiers in Virtual Reality conference was held in 1993 in San Jose, California. Later this conference was renamed and became known as IEEE VR. Bell [9] was among the first to publish a report that described the teaching of VR. Bell offered a two course sequence for final year undergraduate students in computing related majors. Bell's first course focused on supporting technologies for VR. His second course dealt with applications and implications of VR. Unfortunately, despite pioneering efforts by faculty such as Bell, integration of VR topics into the curriculum at colleges and universities was slow. In 2004 Burdea [10] published the results of an informal survey revealing that only about 3% of colleges and universities worldwide offered coursework on VR. In these early years one of the more challenging aspects of teaching VR topics was obtaining appropriate equipment to provide instruction on the subject. A number of low-cost VR systems were proposed as solutions [11]-[13]. A different approach was to have students develop applications for the web using the Virtual Reality Modeling Language (VRML), instead of creating applications that required expensive VR devices [14]. Another challenge to teaching VR was finding a place for the material in already crowded undergraduate computing curriculums. A proposed solution to this issue was to incorporate VR topics into other related courses such as Computer Graphics and Human-Computer Interaction [15]-[16].

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Coursework on VR at colleges and universities worldwide has become much more commonplace since 2004. The availability of relatively low-cost, but high quality VR headsets such as the Oculus Rift and HTC Vive has generated an increased interest in the field, not only from researchers, but from students and faculty in majors across college campuses. With tools such as Unity (unity3d.com) and Unreal Engine (unrealengine.com), developing VR applications has never been easier. Not surprisingly, reports of VR educational experiences at colleges and universities have increased [17]-[22]. Students are often completing VR projects in groups, with typical group sizes ranging from 2 to 4 members [19]-[21]. However, many VR courses are still taught by Engineers and Computer Scientists to students primarily from Engineering and Computer Science (CS) related disciplines.

The author's University has recently placed an increased emphasis on cross-disciplinary educational experiences for students. The author has also made the observation that modern VR applications are often developed and evaluated by cross-disciplinary teams from a variety of academic disciplines such as Art, Computer Science, Engineering, and Psychology. Thus, the author decided to modify his graduate level Virtual Reality course in such a way that it could be open and accessible to students from many majors across campus. The next section describes this course.

III. A Cross-Disciplinary Virtual Reality Course

The primary goal of the course was to create cross-disciplinary teams of students working to build and evaluate thoughtful and meaningful VR applications, with students using skills from their domains of expertise to contribute to team projects. Thus, it was decided that students would need to come into the course with some prerequisite knowledge from their domains of expertise. The author met with faculty from Communication, Psychology, and Media X (a newly created interdisciplinary program focused on digital and emerging media) to discuss appropriate prerequisites and learning objectives for students from these disciplines wanting to take a course on Virtual Reality. Through these discussions it became clear that students from outside of Engineering and Computer Science would be more likely to enroll in the course if it were offered at the undergraduate level. Thus, an upper division undergraduate level special topics course was created, which had as a prerequisite one of three courses: a research methods course (for students from Communication and Psychology), a media creation course (for students from Media X), and a video game development course (for students from Engineering and Computer Science). This undergraduate level special topics course was cross-listed with the graduate level Virtual Reality course, which had graduate standing as a prerequisite.

A. Course Structure

The combined cross-listed course was arranged into three units: applications, foundations, and evaluation. In the applications unit students learned about many contemporary uses for VR in areas such as gaming, therapy, and training. The author also developed a series of Unity tutorials for students to complete as an out of class assignment. The first two tutorials required no previous programming experience and taught students how to use Unity to develop simple virtual environments. The remaining tutorials provided instruction on how to write scripts in C# to create a first-person perspective game for which the player has to find several items in a virtual environment before getting caught by enemy characters. Students were only required to complete the first two tutorials; those with previous programming experience were encouraged to complete the remaining tutorials on scripting. Students then gained practical experience developing VR applications with Unity for the Oculus Rift, HTC Vive, and a large (8 foot by 6 foot) rear projected passive stereo display system that uses a joystick for navigation (shown in Fig. 1 and described in [13]).

Fig. 1. The rear projected passive stereo display system used in the course.

Much of the material covered in the foundations unit aligned closely with that described in [16]. Briefly, students learned about many principles of VR, such as stereoscopic displays, force feedback devices (haptics), viewer tracking, and interface issues often associated with the development of VR applications. These user interface issues included modes of locomotion in VR (such as teleportation, which can help to reduce motion sickness), approaches to assist users as they attempt to find their way in virtual environments (such as providing navigation aids like signs and maps), and techniques for selecting and manipulating virtual objects. Finally, in the evaluation unit students learned how to conduct user studies to evaluate VR applications. Techniques for user-centered design and evaluation of virtual environments [23] were presented, as well as a summary of inferential statistics techniques often used to analyze data collected as part of VR research projects. The purpose of Institutional Review Boards (IRBs) was also discussed, and students completed an online training course required by the author's university for researchers conducting research projects that involve human subjects.

B. Individual Virtual Reality Project

Each student completed an individual Virtual Reality project at the conclusion of the applications and foundations units. The objective of the assignment was to help students formalize their understanding of the material presented in the applications and foundations units, and then apply this knowledge to a project so that students had an opportunity to familiarize themselves with the tools for developing VR. For the assignment students were required to create a 3D virtual environment with Unity that could be displayed using one of the VR systems in the laboratory (Rift, Vive, or passive stereo display system). The minimum requirements for the project were as follows: the display must be in stereo 3D and support head tracking, users should be able to select and manipulate at least three virtual objects, and users should be able to comfortably navigate throughout the entire environment. Using freely available assets it was possible to meet the requirements for the assignment without writing a single line of code, so the students who came into the course with no previous programming experience were able to complete the assignment without having to teach themselves to write Unity scripts. Students presented their projects to the class on the due date.

C. Team-Based Final Project

Throughout the term students worked in teams of two to three to build and evaluate a complete Virtual Reality application. There were several assignments related to this final project. These assignments were as follows.

Final project pitch: At the end of the second week of the term students pitched an idea to the class for a final VR project. Students were allowed to either make a pitch by themselves, or present with a partner. However, if students pitched with a partner they were required to work with a student from a different undergraduate major. Pitches were to describe both the core idea for a VR project and possible roles for members of the team. Team member roles could be any of the following: project manager, programmer, artist, and evaluator.

Cover letter and resume: Students then prepared cover letters and resumes to "apply" for roles on potential final project teams. Specifically, in their cover letters students were asked to state their top four choices for roles on pitched projects and provide resumes to support their choice of roles. The author then read the submissions, selected the most popular project ideas, and assigned students to roles on final project teams.

IRB research application: At the conclusion of the evaluation unit teams created evaluation plans for their final projects. Teams were required to complete the documentation that would be necessary to have their evaluation plans reviewed by the university's IRB. Teams then conducted their evaluation plans. The team's "evaluator" was expected to take the lead on completing these activities. Fig. 2 shows a subject completing the evaluation of a team's final project.

Final project written report: After conducting their evaluations students prepared written reports that described their projects. Undergraduate and graduate students had slightly different requirements for the reports. All students had Introduction, Product Description, and Conclusion sections. Graduate students were also required to write Background and References sections that provided a review of relevant literature, and a Method section that described the team's evaluation. Undergraduate students were required to write Contributions sections that described their individual contributions to the team's final project. Students were also required to follow the formatting requirements for an IEEE VR Conference Paper when preparing their reports. Students completed anonymous peer reviews of three of their classmate's reports. Students then had four days to improve their own reports based on the anonymous feedback from their peers. The author graded only the final written report submissions. These reports made up the bulk of each student's final project grade.

Final project presentation: Instead of a final exam, the class held a "VR Exhibition" in the three hour time period reserved by the University for the course's final exam. Teams prepared posters and interactive VR demonstrations of their projects. Friends, family, colleagues, administrators, and academic advisers were invited to attend the exhibition. An example of a student team demonstrating their final project to an attendee of the VR Exhibition is shown in Fig. 3.

Fig. 2. A subject participating in the evaluation of a team's final project.

Fig. 3. Students from the Virtual Reality course demonstrating their team's final project to an attendee at the VR Exhibition.

IV. Course Evaluation

Twenty-six students completed the course during the spring 2018 term, which included two undergraduate Computer Science students, six undergraduate Psychology students, one undergraduate Media X student, one graduate Education student, one graduate Electrical Engineering student, one graduate Engineering Management student, and 14 graduate Computer Science students (two of whom had undergraduate degrees in Psychology). Students were divided into 10 final project teams (four teams of two and six teams of three). The instructor created teams in such a way as to ensure that each team had students from at least two different undergraduate majors. During the last week of the term students were asked to complete a brief anonymous questionnaire that contained the following Likert scale items:

1. Circle the phrase that best describes your agreement with the statement, "This course increased my understanding of how cross-disciplinary research groups are building and evaluating virtual reality applications."

2. Circle the phrase that best describes your agreement with the statement, "I feel that this course helped to better prepare me to work as a member of a cross-disciplinary team."

3. Circle the phrase that best describes your agreement with the statement, "The workload for my team's final project was distributed evenly among group members."

Each of these items was followed by the following choices:

strongly agree agree neutral disagree strongly disagree

Students were also asked to explain their responses to each item. The questionnaire and administration procedure were approved by the IRB at the author's university. Twenty-five students completed at least some portion of the questionnaire.

For item 1 ("This course increased my understanding of how cross-disciplinary research groups are building and evaluating virtual reality applications"), fifteen students strongly agreed, nine students agreed, and one student was neutral with regards to the statement. A common theme among the comments to this item was that the course increased students' awareness of how VR was used by a variety of disciplines. One student wrote, "I like how the course connected not only material and topics from computer science, media, and psychology but also students from each of these disciplines. The course felt like more than just a computer science class." The student who selected neutral for this item indicated that it became clearer as the course went on.

For item 2 ("I feel that this course helped to better prepare me to work as a member of a cross-disciplinary team"), eleven students strongly agreed, ten students agreed, and four students were neutral with regards to the statement. One student who strongly agreed with the statement wrote, "It was a refreshing experience to work {with} other majors and dividing the work into different roles that matched each of our abilities." One of the students who indicated neutral wrote, "Even though the class did explain cross-disciplinary group research, it was not overly clear as to what is really done in those teams." Perhaps these comments suggest that the author could do more to make roles and responsibilities of team members clearer to students.

For item 3 ("The workload for my team's final project was distributed evenly among group members"), seven students strongly agreed, six students agreed, five students were neutral, four students disagreed, and three students strongly disagreed with regards to the statement. Among those who disagreed or strongly disagreed, five made comments indicating that they felt a teammate did not contribute responsibly to the project. Another student suggested that adequate guidelines were not provided to help students "coordinate with someone from another field." Among students who indicated that they were neutral with regards to the statement, the most common theme was that the kinds of work different team members were asked to do were not equal in difficulty or the amount of time that they took to accomplish. Some students suggested that the programmer's role was most time consuming.

V. Conclusion

This paper describes the author's efforts to develop a virtual reality course for which students work in cross-disciplinary teams to build and evaluate VR applications. Responses on an end-of-term questionnaire suggest that, while many students did believe that the course better prepared them to work as members of cross-disciplinary teams, some aspects of the course could be improved, such as making team member roles clearer, and helping students learn to work more effectively with classmates from other disciplines. Methods to balance the workload among team members should also be sought.

One of the more challenging aspects of the course for the author was trying to place students on project teams they were interested in, while also ensuring that teams were cross-disciplinary with the appropriate set of skills to build and evaluate the projects. In their cover letters students were asked to apply for specific roles on specific project teams. In the future, students will be required to indicate which of the roles they feel most qualified to perform in the first line of their cover letter. If they believe they are also qualified for a second role, they will be asked to explain this in the second paragraph of their cover letters. Following their explanations of roles, students will be asked to indicate their favorite project pitches. Students will then be assigned to teams with role qualifications as the primary consideration; interest in the project will be of secondary importance when assigning students to teams. Since some students suggested that the programmer's role was most time consuming, it may also help to attempt to assign at least two students with programming experience to each team, with one of these students having programmer as a secondary role.

In the future, the author also plans to incorporate elements of Scrum [24] into the course. Scrum is an agile methodology for managing teams that is often used in the software industry. The author has had previous success using Scrum to manage a cross-disciplinary team of undergraduates that developed a virtual heritage application over a period of five weeks [25]. The students who worked on the virtual heritage application indicated that the regular meetings encouraged by Scrum were helpful as they learned to collaborate with teammates from other disciplines. For the next offering of the VR course, once teams begin to work on their final projects, the author plans to allow a few minutes at the end of each class period for short team meetings. Teams will also be required to produce runnable VR prototypes every two weeks. This may help to improve coordination among team members and ensure that students contribute responsibly towards the work of the project throughout the term.

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