Exploring Factors Associated with Retention in Computer Science Using Virtual Reality

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ABSTRACT

In this research, the goal was to dissect the main attributes associated with student engagement in introductory Computer Science (CS) courses. A Virtual Reality simulation and survey were designed. Results indicated that there was a strong positive reaction to goal orientation, and a strong negative reaction to demographic characteristics.

Index Terms: Applied computing—Education—;—— Human-centered computing—Human computer interaction (HCI)—Interaction paradigmsVirtual reality; Human-centered computing—Human computer interaction (HCI)—HCI design and evaluation methods—User studies

1 INTRODUCTION

There has been a persistent decline in the number of underrepresented minority (URM) students entering computer science (CS) and technological majors for several decades [7]. This decline has resulted in lower rates of employment in STEM fields (especially technology fields) for URM populations during a time when there is an excess of technology-related careers to go around in this country [14, 20]. There is plenty of evidence to suggest that diversity is a major contributor to innovation and a variety of backgrounds are crucial when developing new ideas [12, 22]. Therefore, solving the problem of underrepresentation (as defined by the National Science Foundation (NSF) as women, African Americans, Hispanics, Native Americans, and indigenous peoples [3]) is pivotal in the coming years as new innovative technologies become necessary to combat society's ever-growing challenges.

Before diversity can spread within technological industries, the reasons behind the decline must be explored and properly dealt with. The research being pursued in this project is a unique avenue toward the goal of solving the underrepresentation problem in CS and other technological fields. A lack of belonging has been identified as a major contributor to diverse populations' lack of interest in some majors [28] and especially technological fields of study [16]. For this reason, it is pivotal to understand where a sense of belonging commonly originates among people entering college. The factors described below are all associated with belonging in some way. These four factors are the focus of this project.

1.1 Family Background

Early role models often influence a person's sense of belonging in a given discipline [25]. There is a limited amount of research on how belonging impacts people considering CS specifically. As a relatively new field of study, many people have no exposure to CS early in life. Men have dominated technological fields for decades [14]. Since attempts at mitigating the inequality in this field have not been particularly successful until recently we are seeing the effects of the inequality in the next generation preparing to get an education. Many people who are exposed to CS at a young age only witness male figures in the field, often making the field feel less accessible to young women [18]. This suggests that the impact one's family background has on their willingness to participate in something new to them is significant.

1.2 Self-Efficacy

Self-Efficacy is defined as a person's level of confidence in their ability to achieve a desired outcome [8]. Self-efficacy is clearly a more psychological phenomenon than a person's family background, therefore combating a lack of self-efficacy should look different than making up for a weak family background in CS. CS is not strongly related to other fields. Many people are only exposed to images of highly advanced Computer Scientists in the media. Due to these realities, people automatically believe the study of CS to be out of reach. A person is much less likely to feel a sense of belonging in a field they do not believe they could excel in [17].

1.3 Goal Orientation

Goal orientation in CS has been recently researched and discovered to be a significant factor in a students desire to purse a career in CS [16]. Many people do not believe that a degree in technology can offer them a career that will allow them to attain their goals. Work done by Colleen Lewis et al. suggests that many people believe that CS jobs are all desk jobs in which they would be forced to do math and difficult coding all day [17]. The same study suggests that people desire more than this. People want to see their work make a difference [26]. The field of CS has many different facets that the general population are simply not aware of. For example, developing Geographic Information Systems (GIS) from a human-centric computing perspective would have computer scientists explore the areas themselves before charting the area if possible. Or doing research for organizations devoted to improving technological access to developing countries. Exposure to the different careers and opportunities CS offers is likely to increase a person's sense of belonging in the field.

1.4 Demographic Characteristics

For this project, demographic characteristics are defined broadly as a person's racial/ethnic, cultural, and gender identity. Many researchers have identified that there is a distinct lack of well distributed multiculturalism in CS [10, 23, 29]. For example, in 2014, of the intersectional hiring being done by Google, about 1.2% were black women. In 2019, that percentage had risen by one percent [1]. Google is a company that puts a lot of energy into diversifying their employees and they still struggle to see significant growth. In the majority of research done on the effects of belonging on URMs in CS the results are always fairly similar. People who have a demographic identity that is dissimilar to the majority in their CS courses or in their CS work tend to have a more difficult experience [29]. The results of this research are widespread and well-known even by those outside of the field. The consequence is that people who do not feel they will have a community in CS may not wish to attempt joining the field. If there was some sort of assurance that they would

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have a community in CS then perhaps they would be more inclined to feel a sense of belonging [29].

It is important to make clear that all these factors are at some level intertwined. For instance, a student's family background is likely to impact their self-efficacy in a given field. However, the approach to addressing these four different factors varies drastically. If people have a highly positive reaction to an appeal to their goal orientation and a negative reaction to highlighting their demographic characteristics, career opportunities being advertised to incoming freshman would likely be more advantageous than emphasizing meet and greets with students of the same racial identity. Actionable initiatives can be constructed that are targeted at specific problem areas through parsing these factors out, and determining whether or not they are equally important to people when choosing to enroll in CS.

1.5 Incorporating Virtual Reality

Virtual reality (VR) is one method of exploring belonging in CS without personal experience adding as much variation to participant responses. VR has been used to elicit emotional responses before [11, 19]. Using VR to determine how people feel in a controlled setting has not been explored thoroughly. VR creates a controlled setting for experimentation especially when it is kept simple [27]. For this user study, VR allows the participants of the experiment to feel connected with the avatar (i.e. virtual agent within a virtual environment) they will embody. However, the subject recognizes that the avatar is not meant to represent them. This is likely to result in responses that reflect how much weight participants give to each factor associated with belonging.

2 Literature Review

The field of CS education has many papers investigating the problem of diversity [16, 18, 24, 25]. The results of most of these studies suggest that increasing diversity is a complex issue that cannot be solved in any singular way. Some papers have tried applying Self-Determination Theory [18], which is a model in behavioral science that attributes a person's internal reward system as a key aspect of their motivation to achieve. Others have tried encouraging students to get involved with formal research experience early in their academic careers [24]. Academic initiatives are constantly being integrated into schools targeted at diverse minorities [5]. Many of these studies focus on including more women in CS [5, 18, 25] but according to some of the most recent research it is not just a gender problem [16, 28].

Recent research that has explored belonging in CS has focused on the levels of belonging that exist in diverse minority students [16]. Lewis et al. [16] have drawn the conclusion that underrepresented minorities in CS have a significantly lower sense of belonging in their major than other students. The students who do not believe CS can be used to achieve communal goals are the students who feel the least sense of belonging in the field. Communal goals being objectives that are achieved by helping others or being of assistance to something beyond oneself. The students who are not underrepresented who also seek to achieve communal goals are far more likely to consider CS an avenue to achieve these goals than underrepresented students. This suggests that underrepresented students are not being exposed to the many ways CS can be applied to future careers.

A recently published study on using a growth mind-set to improve academic performance in CS was unsuccessful at significantly improving academic performance but they did find that student interest in CS increased [6]. Since this project is focused on enrollment the results from the study done by Burnette et al. [6] are particularly valuable. The psychological approach of a growth mind-set is strikingly similar to what an initiative to improve self-efficacy would look like. The idea is not to externally change the environment students are exposed to, but internally change a student's perspective. The Burnette et al. study [6] indicated no difference in response between genders. This observation suggests that a more psychological approach to improving CS enrollment is not biased toward women, but helpful for all students.

A related study was able to find resilience to be extremely important for performance in CS courses and important for retention [21]. Resilience is another cognitive process very similar to self-efficacy. This study specifically examined the responses from first-year undergraduate CS students which makes it highly relevant to the project discussed in this report.

A person's identity is often discussed in literature related to CS education. Identity is key, especially now that narrative has been shown to have an amazing influence on people's interest in CS [13, 15]. A narrative perspective as it relates to CS varies slightly between studies but it is always based on students' backgrounds. Constructing narratives around new information that incorporates subject matter that relates to a diverse set of experiences has been shown to really support the learning process [15]. A study found that women often find their identity threatened when considering entering the CS field [9]. The participants in this study done by Cheryan et al. [9] felt that they would not succeed if they did not repress some aspects of their femininity.

The research discussed above all informed the choices made for the project moving forward. These articles indicate that there is evidence to support the idea that there are all sorts of factors that are involved in a person's decision to choose CS and stay in CS. What these papers lack is perspective on whether what they have found to be significant is, in fact, the most significant factor involved in a student's sense of belonging.

3 Contribution

This experiment provides a basis for exploring peoples' sense of belonging in CS in a controlled virtual environment. It attempts to remove personal bias and better understand what belonging means to people as a concept rather than a person's own experience with belonging in the CS field. This project dissects belonging into four factors: self-efficacy, goal orientation, family background, and demographic characteristics. These factors are evidently involved in a sense of belonging as well as a student's choice to enroll in CS. This research explores differences in response to these four factors individually rather than as a whole. The data from this work can be used to develop specialized initiatives that reflect what people really find important when choosing to enroll in CS.

4 Apparatus

All the hardware and materials are described to provide enough information for reproduction by other researchers.

4.1 Unreal

Unreal Engine v4.23 [4] was used for development of the final simulated environment. Unreal provided the ability to develop a mirror using assets integrated into the basic architecture of the software. Unreal allowed the use of more detailed assets and had the ability to import avatars that were high quality.

4.2 Virtual Environment

The avatar was placed seated behind a desk directly facing a mirror on the back wall of a small room. The room had a door, a light and a small painting as decoration. The desk displayed a cell phone used to listen to the audio cues.

The mirror used needed to not create any distortion and needed to be able to handle the bi-ocular nature of VR. Assets that were designed by other developers were intentionally blurred, projected a duplicate image when using VR, or portrayed a distorted image.

Table 1: Transcript of the audio cues from the final experiment

Goal Orientation
Hello, this is the office of registration and advising in the Computer Science department at UniversityX. We are contacting you because our records indicate that you have not yet declared a major and we would like to encourage you to enroll in an introductory Computer Science course. With a background in Computer Science, you will have many opportunities to contribute new technologies and innovations to your community and the world. If your goal is to help others Computer Science may be right for you. Would you like to enroll?
Self-Efficacy
Hello, this is the office of registration and advising in the Computer Science department at UniversityX. We are contacting you because our records indicate that you have not yet declared a major and we would like to encourage you to enroll in an introductory Computer Science course. Your transcripts indicate you did not take a Computer Science course in high school but with your high grades and drive to succeed that you make clear in your essay you should have no trouble in Computer Science. Would you like to enroll?
Family Background
Hello, this is the office of registration and advising in the Computer Science department at UniversityX. We are contacting you because our records indicate that you have not yet declared a major and we would like to encourage you to enroll in an introductory Computer Science course. According to your personal records, your mother and father are both in tech fields. Despite never having taken a Computer Science course before we expect that you would have no trouble adapting to the demands of the course due to your life-long exposure to the material. Would you like to enroll?
Demographics
Hello, this is the office of registration and advising in the Computer Science department at UniversityX. We are contacting you because our records indicate that you have not yet declared a major and we would like to encourage you to enroll in an introductory Computer Science course. This department strives to be as inclusive as possible and we believe that you will feel a strong sense of community among your peers according to your gender and ethnic profile. Would you like to enroll?

Since it was essential that the participants felt somewhat embodied in the avatar the mirror was a crucial part of the simulation. Unreal allowed development of exactly the mirror desired very quickly.

4.3 Avatars

Participants were matched with avatars that reflected their preferred gender and ethnicity. This allowed participants to feel as embodied by the avatar as possible during the simulation. The avatars imported for this experiment were created on Mixamo an Adobe affiliate [2]. Some animations were added to the avatars based on the feedback received from the pilot study. The participants could see the avatars breathe in the mirror and when they looked down at the avatar's body.

4.4 Audio Cues

The audio cues used in the simulation were formatted as voicemail messages. This was done so that participants wouldn't feel the need to respond verbally to the questions asked of them. A female disembodied agent introduced herself as a worker at a college department advising office. She prompted the participants embodying avatars, highlighting the four factors discussed at length previously. The transcript of the voicemail for each condition can be found in Table 1.

4.5 Survey

The survey took about 10 to 15 minutes to complete. It was developed to garner how likely the participant was to enroll their avatar in the CS course offered with only the information highlighted in each condition. Each question used a 5-point Likert Scale (1 - not at all, 5 - extremely likely). The survey was also used to collect demographic information about the participant.

5 Procedure

In this section, the entire process of running the experiment is detailed. This was a repeated measures experiment meaning that every participant performed each of the four treatments.

5.1 Participants

For the final experiment, there was a total of 25 participants. One participant's results had to be discarded due to an error made when filling out the survey (n= 24). The participant pool was comprised of mostly white (86.4%) males (63.6%). The majority of participants were undergraduates in CS fields (59.1%) and between the ages of 18 to 22 (45.5%). 31.8% of participants were between the ages of 23 to 27 and 22.7% were over the age of 28. Nearly all participants were currently in college pursuing a degree. All of the participants had no prior knowledge of the intent of this study when they agreed to volunteer to do the experiment. Several of the participants agreed to do the study in exchange for course credit but the majority were strictly volunteers. Due to the fact that many of the participants were in CS fields they had some exposure to VR but many participants had never experienced a virtual environment before.

5.2 Different Versions

This experiment was developed to work in a virtual environment using an Oculus Quest with computer linked cable or any head-mounted display (HMD) that could connect with a Windows Personal Computer. The file needed to run the simulated environment was a .EXE file so any computer that could run a .EXE file could be used.

The experimental simulated environment was also able to run on a desktop without a HMD. The experiment was designed to support both options so as to allow more accessibility for potential participants. Very few participants used the desktop version of the experiment (9.1%) making it difficult to determine if there was a significant impact on the overall experience for the participants. The experiment was designed to be done remotely, if necessary, again, in order to allow for more accessibility to potential participants.

5.3 Running the Experiment

Participants who ran the simulation remotely were instructed to read the instructions provided completely before moving forward. They were then instructed to download the simulated environment which contained the avatar that best represented their gender and racial identity (i.e. Light_Skinned_Male_VR). The folders that contained all necessary files for running the simulation could be found on Microsoft OneDrive. Once the files were downloaded (20 minute download time at low processing power) the participant was instructed to find the executable file called *project2.exe* and answer the first question on the survey. They then opened the executable file and then put on their personal HMD if they had access. If they did not have access to a HMD they opened the executable file and used their mouse to look around the simulated environment. All participants were then asked to select and remember any number between 1 and 4 on their keyboard. The number key triggered one of the four audio cues. Once the audio cue completed playing they were asked to remember the four digit number that appeared over the top of the cellphone in the simulation. Once they had the number memorized they could remove the HMD and/or go back to the survey. They then filled out the next three questions on the survey asking them which

condition they had just completed, what the condition was highlighting as a means of determining if the participant was listening closely, and how likely they were to enroll in the CS course discussed in the audio cue. Remote participants were also asked to provide the four digit number to ensure completion of each condition.

All participants entered the simulation four separate times to experience each audio cue. The remote participants were asked to randomly select the triggering keys to avoid ordering effects. After they had listened to all audio cues they were asked to complete the remaining questions on the survey before they finished the experiment.

Participants who signed up to run the experiment in-person had a very similar experience. After signing the consent form they were asked to answer the first question on the survey which acted as a control question to see how likely the participant was to enroll in an introductory CS course without any treatment. They were then instructed to read the first section of the instructions provided as well as the section introducing the avatar they would be embodying. This section reads as follows:

"In the simulation you will be embodying a first-year undergraduate student who has yet to declare a major. This person has not taken any computer science courses in the past. You should take everything suggested in the audio cues as fact."

The participants then put on an Oculus Quest with computer link cable. A researcher used a bluetooth keyboard to open the simulation executable and randomly select an audio cue to play. The participant was instructed to remove their HMD and answer the questions associated with the condition they just completed. The participants were told which condition they had just been through. When the participants performed the experiment in-person they were not required to remember a four digit code after each condition. Participants went through the simulation four times in order to complete all four conditions. After they had completed all conditions and filled out the entire survey they submitted the survey and their part was finished.

6 Methods for Evaluation

Analysis was completed using a linear mixed-effects model. A linear mixed-effects model accounted for the within subjects design of the experiment. This model accounts for a participant's data points correlating with one another since they come from the same participant as well as the variability at the subject-to-subject level. The fixed effects for this model were the various audio cues because this study was interested in the effect of the audio cues on participant response, and if the effect varied depending on the highlighted factor in a given cue. The marginal sum of squares obtained by deleting one term from the model at a time was used when running an analysis of variance (ANOVA) test comparing the means between conditions.

7 Results

Participants strongly favored the condition of the experiment which emphasized goal orientation seen in Figure 1. Participants appear to favor the condition which emphasized self-efficacy, but response to the self-efficacy condition were widely spread among participants. Participants indicated a substantial decline in interest in the course when the emphasis was on their race and ethnic background. Family background had a neutral response among participants which Figure 1 shows most clearly with 40% of participants responding with 'not likely or unlikely'.

Since there was a substantial difference in responses between conditions across participants as shown by an ANOVA test ($F = 9.484$, p ¡ 0.0001) there was enough evidence to contrast each condition. The results of those contrasts are shown in Table 2. There was a difference in means between most conditions except self-efficacy compared to goal orientation and demographics compared to family background.

Table 2: Summary table of contrasts between treatments

Contrast	Estimates	SE	DF	T Ratios	P Values
Ability - Demos	0.875	0.247	69	3.539	**0.0040**
Ability - Family	0.750	0.247	69	3.033	**0.0175**
Ability - Goals	-0.208	0.247	69	-0.843	0.8340
Demos - Family	-0.125	0.247	69	-0.506	0.9575
Demos - Goals	-1.083	0.247	69	-4.381	**0.0002**
Family - Goals	-0.958	0.247	69	-3.876	**0.0013**

8 Discussion

The demographic characteristic condition and the goal orientation condition are significantly different ($p = 0.0002$). This suggests that there is a difference in attitude toward enrollment depending on which factor of belonging is emphasized.

Figure 1 indicates that participants were fairly negatively affected by the emphasis on demographic characteristics. It is true that a person's beliefs do not always align with their behavior. This phenomenon is referred to as cognitive dissonance. This research is not suggesting that people would not feel a stronger sense of belonging if they were surrounded by others that reflect their demographic identity. This **research does indicate** that when a person is told that they will find a similar demographic community in CS it does not encourage them to want to attend. It may also be worth noting that the majority of participants in this study represent the demographic balance in the CS community as it is now, which is dominantly white males.

The fact that so many of the participants showed such strong favor to goal orientation is in alignment with the work done by Colleen Lewis et al. [16]. These results indicate that when choosing a program of study, knowing the copious amount of opportunities in that field is extremely important to people.

8.1 Feedback

While the majority of participants were in a field related to CS and gave high scores to the initial question of "How likely are you to enroll in a CS course?" their responses were much more varied after being put in the simulation. This phenomenon might be due to the simulated environment having the desired effect. The simulated environment allowed participants to have a depersonalized experience and answer the survey questions as the avatar rather than as themselves.

Participants noted in survey feedback that they would have liked to see even more movement in the avatar to increase the embodying effect. In order to accomplish this, a change in the type of HMD may be advisable in future work. The feedback on the survey was largely positive though, one participant mentioning that they could empathize with the avatar more being embodied in it.

9 Future Work

The work done in this project is highly nuanced since the alterations between conditions are very minor, but it has a clear direction forward. Since the results of this project seem to indicate that there is a preference for what will encourage students to enroll in CS courses the same study should likely be repeated with more participants and with different audio cues that communicate the same ideas but are stated differently. Not only should their be more participants, but the participants should include more diverse voices. The majority of participants were CS majors already, and none of the participants were undeclared. The participant's major did not seem to have a large impact on the way they responded but there was not enough data to make a claim about the impact of major.

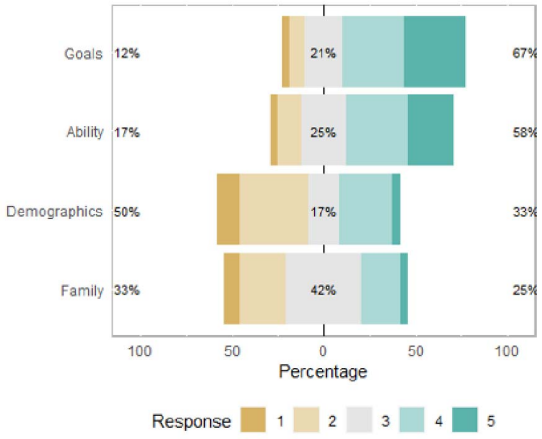

Figure 1: A bar graph of likert scale responses from participants concerning their interest in taking a CS course

If the results of this study remain similar upon repetition with a larger and more diverse sample then there may be evidence enough to begin working on actionable initiatives that are considerate of the data gathered.

There are also plenty of improvements that could be made to this experiment design. The four factors that were highlighted in the final experiment were supported with evidence that suggested that they were important to a student's sense of belonging, but there could easily be more factors that were not investigated in this project and deserve to be. There was some feedback from participants saying that they could have felt more embodied in the avatar if it were capable of moving with them. For this project, a more focused virtual environment rather than an interactive one was chosen, but it is possible that the results would have been less biased with more avatar control. The virtual environment itself was somewhat sparse, so improvements to the space that would make it feel more immersive would also likely lead to a more embodying experience.

10 Conclusion

Despite the promising outcomes achieved by this study there were many areas of this research that could be improved upon. In many ways it was a pioneering effort into the world of uniting VR and psychology. Research into the power of VR to create psychologically "sterile" environments, where subjects can lose themselves but still draw conclusions about what they are experiencing is difficult to find. In psychology, it is vital that subjects are in a controlled environment when results are being collected and VR allows researchers to control the environment in ways that were impossible in the past.

This work is a deep examination into the minds of people. It is a chaotic area of research, that is constantly susceptible to change and modification. The results of this study will almost certainly change over time, but it is critical that education researchers persistently try to maintain an edge on what goes through a student's mind, especially when making major decisions for their future.

The research done in this project unfortunately did not encompass an extremely diverse set of people. It is important that the conclusions drawn from this project be reexamined on the population it was designed to help address the needs of. Researchers have a responsibility to aid in bringing students into universities that belong there. Whether a student belongs in CS because their goals require a technology background, they have the confidence to succeed in the field, because of their family, or because their demographic characteristics give them a unique opportunity to provide insights that would not have been explored without their presence. People of all backgrounds are necessary for the future of this field.

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