

Improving Student Appreciation for Universal Design Using a Simulation-based Comparative Approach

Colin Depradine

*Department of Computer Science, Mathematics and Physics, Faculty of Science and Technology
The University of the West Indies, Cave Hill Campus, Barbados*

An introductory Human-Computer Interaction course exposes students to the guidelines, processes and models used in the creation of usable interactive software systems. These concepts revolve around the principle of user centeredness, where the user is the focal point of the software design. However, one area that tends to be overlooked is that of universal design; the process of designing user interfaces for as many users as possible. This article presents the results of an action research study in the use of a preliminary assignment to introduce 37 computer science students, which represented the entire course, to the importance of universal design. Students were provided with the opportunity to construct knowledge via a comparison exercise using software development tools developed specifically for teaching universal design. The results were analyzed using the SPSS statistical analysis tool. The major findings were that students' appreciation of universal design increased, however, greater time to complete the assignment may have led to better overall results.

Keywords: Computer Science Education, Universal Design, Human-Computer Interaction

Introduction

The ACM Special Interest Group on Computer-Human Interaction (SIGCHI) defines Human-Computer Interaction (HCI) as “a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them.” (ACM SIGCHI Curricula for Human Computer Interaction).

With this in mind, an introductory HCI course offered under the discipline of Computer Science will typically focus on the fundamental design issues of user interface creation for computer software. Students are introduced to a variety of development processes, guidelines and best practices. One example is the Interaction Framework, which provides a framework for modeling the interaction between the user and the computer system (Dix, Finlay, Abowd & Beale, 2004). Students are also introduced to several rules-of-thumb that are a collation of several years of research such as the Eight Golden Rules of User Interface Design by Shneiderman & Plaisant (2005), which provide useful broad guidelines on the creation of usable user interfaces. In addition, case-studies are used to demonstrate the various HCI techniques that were employed when solving specific problems. These case studies provide reference points for

*Email: colin.depradine@cavehill.uwi.edu

students when tackling real-world problems (McCrickard, Chewar& Somervell, 2004; Smith, Vega & McCrickard, 2008; Carroll & Rosson 2005).

One topic that is usually briefly introduced is that of universal design or the art of designing user interfaces for as many different user types as possible. In order for students to gain experience with universal design, it is necessary to create opportunities that allow them to fully explore the concept. One approach is at the assignment level where universal design is the focus. However, one of the major hurdles is access to software tools that enable students to experiment with the design issues that can occur when creating software for non-typical users. Assignments focusing on this area would typically require the student to build the required user interface components. This can have the disadvantage of reducing what the students can achieve in the limited time period.

This paper explores the use of an assignment to explore the topic of universal design. Students were required to create user interfaces for two different user types, for the same problem. They were given the assignment, near the beginning of the semester, with the hope that such early exposure would produce a greater appreciation of the need for such design techniques. Given this proposal, the research questions were:

- *Can an intervention focused on universal design increase students' appreciation for the area?*
- *Would inclusion of an extra assignment depreciate students' appreciation for the topic of universal design?*
- *What effect would the inclusion of this assignment have on students' performance in the final major project?*

Literature Review

Universal design states that the product under consideration should be designed to be used by as many people as possible in as many situations as possible (Dix et al., 2004). In other words, during the creation of any product, the design should avoid any specific attribute that deliberately discriminates against a specific type of user.

The Seven Principles Universal Design

The seven general principles of universal design were developed at North Carolina State University in the 1990s (Story, Mueller & Mace, 2014; Dix et al., 2004). While these principles deal with design in general, they can be applied to interactive user interfaces. The seven principles are summarized below.

1. **Equitable use:** The item in question should be useful to as many people as possible without stigmatizing.
2. **Flexibility in use:** In order for a product to be available to a wide range of users, it must cater to the expected wide range of abilities and preferences.
3. **Simple and intuitive to use:** To be universal in nature, the product must be intuitive and simple to use. With respect to intuition, the user should be able to use their existing knowledge to deduce how to use the system. In the case of simplicity, achieving a specific goal should require as few steps as possible.
4. **Perceptible information:** Information must be able to be displayed in multiple ways to cater for different user preferences, needs and abilities.

5. **Tolerance for error:** The system must be able to minimize the damage caused by user error and would include the ability to undo changes.
6. **Low physical effort:** For users in general, ergonomic issues can have a dramatic effect on performance. Systems that require awkward or difficult physical maneuvers will in time cause discomfort and fatigue.
7. **Size and space for approach and use:** The location and size of the system also plays an important role. This not only applies for physical exertion but also the effort required for manipulating objects on a computer screen.

Use of Universal Design

The concept of universal design is a generic term used to describe the creation of processes and items for as wide an audience as possible by utilizing as much flexibility as possible. The area commonly associated with universal design is accessibility for the disabled and the elderly. This can be found in a variety of areas such as the design of buildings, the creation of educational objects and the development of software. Siu (2011) discusses how universal design can solve the accessibility issues of public toilets which focus on those with motor disabilities but ignore the visually impaired. Rivera-Nivar and Pomales-Garcia (2010) discuss the issues involved with developing online training modules for users of differing ages using universal design guidelines. Sayagoa and Blat (2010) show how age affects the perception and use of e-mail by older people while Becker (2004) discusses the age factor in terms of the use of the Web. Inkpen (2001) shows that the point-and-click method is easier than drag-and-drop when considering children as the user group.

In the area of education there is a growing body of work focused on creating educational assets that are universally accessible. Sapp (2009) describes an early system focused on the development of an e-learning system for students with both learning and physical disabilities. Basham and Marino (2013) discuss the use of universal design for learning techniques to make STEM (Science, Technology, Engineering and Mathematics) education accessible to students from either end of the spectrum, exceptionally gifted children to those with learning difficulties.

Lombardi and Murray (2011) discuss the creation of a survey instrument to determine the attitude of faculty towards adopting universal design principles in the creation of their educational content. For universal design for learning to be successful, faculty must be willing to adopt the principles.

Udo and Fels (2010) discuss the need for universal design in the creation of close captioning and audio descriptions. Close captioning is used to provide text representation of spoken dialogue for the hearing impaired, while audio descriptions is a second audio stream used to provide descriptions of important visual elements in the film or television show to the visually impaired. Bjork (2009) discusses the consequences of not utilizing universal design in normal product design, such as suffering a loss of competitiveness and a reduction of market share.

Given the rapid spread of powerful mobile devices, decreasing hardware costs and the increasing economic strength of physically disabled and elderly users, the area of universal design must take on a greater role within commercial software development. For example, sound, containing rich information, plays an important role in the design of web browsers for blind users (Takagi, Saito, Fukuda & Asakawa, 2007; Yesilada, Stevens, Harper, & Goble, 2007; Hochheiser & Lazar, 2010). There have also been some attempts to develop frameworks to guide the developer (Obrecovic et al., 2007).

HCI Assignments

Given the previously discussed issues, it is critical that the topic of universal design be included in the Computer Science curriculum. One method for reinforcing the universal design principles is direct experience with the issues at hand. By placing students in situations where the specific HCI issues are experienced, they are given the opportunity to construct knowledge around those experiences. Given the user centered nature of HCI, it has been argued that one of the best forms of experience is the solving of a real-world problem. As Coppit (2006) shows, not only are students exposed to the area of teamwork but it gives students the opportunity to put into practice what was learnt within the course. This approach introduces some of the complexities associated with the real-world application of theory (Whiddett, Jackson & Handy, 2000).

One of the more pressing issues is how to introduce universal design into an already crowded Computer Science curriculum. As discussed by Liffick (2005), Poor et al. (2012) and Waller, Hanson and Sloan (2009), one approach is to create entire courses or programmes that include or focus exclusively in this area. A more realistic approach is to incorporate the topic into a Human-Computer Interaction course. While this approach cannot go into the required depth, it still ensures that students are introduced to this area. Poor et al. (2012) demonstrate that greater incorporation of accessibility engineering or universal design into an HCI course can increase a student's awareness of the importance of usability.

Human-Computer Interaction Course

The Human-Computer Interaction (HCI) course is a level III course which began in the academic year 2008-2009 and is offered annually. The primary focus of this course is to teach students how to produce user interfaces that meet the needs and expectations of the users. One important topic of the design section of the course is universal design.

Initially, coursework consisted of a series of small tasks and a final major project. The tasks were generally made up of computer lab-based exercises exploring some of the issues discussed in class. The major project formed 20% of the overall mark. Groups of students were required to develop a major software application to solve a problem using fundamental HCI techniques taught throughout the course.

Universal Design Assignment

Before the academic year 2011-2012, all groups completed the major project but at the same time made errors in the overall design and function of the user interfaces. The errors were a result of assumptions based on societal generalizations and personal experiences. In many cases, students attempted to create user interfaces for users with physical impairments by creating user interfaces for regular users and then extending them, with minor changes to other groups. In other words, students either did not understand the concepts of universal design or did not see the need to apply it.

Consequently, it was decided to add an additional assignment to focus on universal design. It was hoped that this new approach would increase the student's awareness of the concepts of universal design. This assignment focused on the development of software for the blind and was used for two consecutive academic years, 2011-2012 and 2012-2013. It was felt that the assignment would provide students with the opportunity to explore some of the issues involved with creating user interfaces for users with varying physical disabilities.

Given the short time span of the assignment, approximately 3 weeks, the necessary software tools, code libraries and application programming interfaces (API) were supplied. The

tool provided to the students for the development of software for the blind, called the AUI (Audio User Interfaces) system, was developed internally. The AUI system is built using the internally built ADG software development kit, as shown in figure 1. It provides access to the features needed for developing audio based software such as text handling, audio handling and speech synthesis. It was developed using the Microsoft .NET framework (Microsoft .NET Framework and .NET SDKs, 2014). Students can utilize the ADG via any .NET supported programming or via the custom builtXML based scripting language.

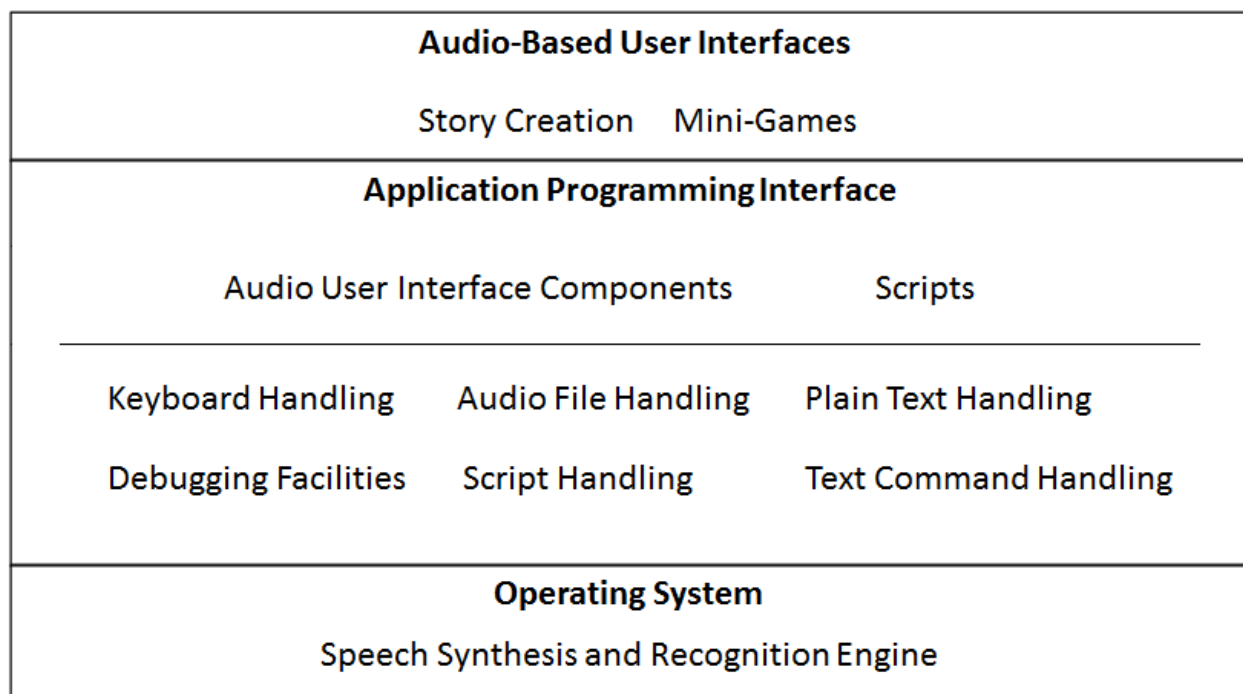


Figure 1.ADG Architecture

This was a preliminary test to determine the viability of the approach and whether or not it was beneficial. Overall, the students demonstrated a greater awareness of user centeredness and tried to apply the concepts in their final projects. However, a number of issues arose.

- The use of another programming language (in this case XML) was found to be difficult to learn in the short time given.
- The APIs allowed for a large degree of programming freedom but were found to be too complex for the short time period.
- The creation of the audio files took considerably more effort than was anticipated.

At the end of the assignment, students were asked to complete a questionnaire that looked at the student's experience with the software. One question focused on the lessons learnt, "What lessons did you learn?" For both years, the comments can be summarized as follows.

- Developing software for blind users or those with physical issues is difficult.
- Creating audio-only software is difficult.

Students did realize that creating software for the blind was a much harder task than they anticipated but the overall lessons learnt revolved around the difficulty in completing the assignment and not the overall concepts of universal design.

In spite of these difficulties, there were improvements in the final major projects and the overall performance. However, what was not clear, was how the difficulty level of the assignment affected the student's overall attitude towards universal design.

Current Assignment

In the academic year 2013-2014, it was decided to undertake a more formal examination of the universal design assignment approach. To address the issues with the previous attempts, a new set of software tools were developed. Also, the assignment was modified so that students were given the opportunity to compare designing user interfaces for two distinct groups, sighted and blind users, using the same data.

For the purposes of this assignment, a new software tool called GameUI was developed, which provided the data stream required for the two user groups. Figure 2 shows the output of the GameUI sample code provided to the students. In this case simple circles and numbers are utilized to represent the data stream. The GameUI system also enables the use of audio to represent the same data.

The GameUI system consists of the original AUI tools wrapped in a new simplified API, as shown in figure 3. This removed the need for XML but introduced the need for the C# programming language (Microsoft, C# Fundamentals for Absolute Beginners). The preferred programming language would have been C++ due to the students' prior experience with the language (Microsoft, C++ Language Reference). However, to use C++ for the .Net based API would have resulted in the use of too many non-standard C++ features, which the students were unaware of. Given C#'s similarity to the C++ and Java programming languages, it was also felt that students having undertaken a course in C++ and with over 80% indicating that they have completed the course in Java programming, C# would be easier to grasp (Oracle Technology Network: Java). The API was made simple enough that students did not have to learn the C# language in its entirety. They simply needed to know how to call functions via an object-based approach and with their prior programming experience, they already knew how to do this.

From a programming perspective, this system provides two sets of APIs, one for graphical user interface components and one for audio based programming. The first one allows for visuals (graphics) to be developed for sighted users while the other is for blind users. The data was generated at a rapid rate so that students could not take the easy way out and simply display/playback the data to the user. In this case, the available visual components could display data at a faster rate than the audio components. This meant that students could not simply develop the user interface for sighted users and then modify it for blind users. Instead, equal effort was required for both user interfaces.

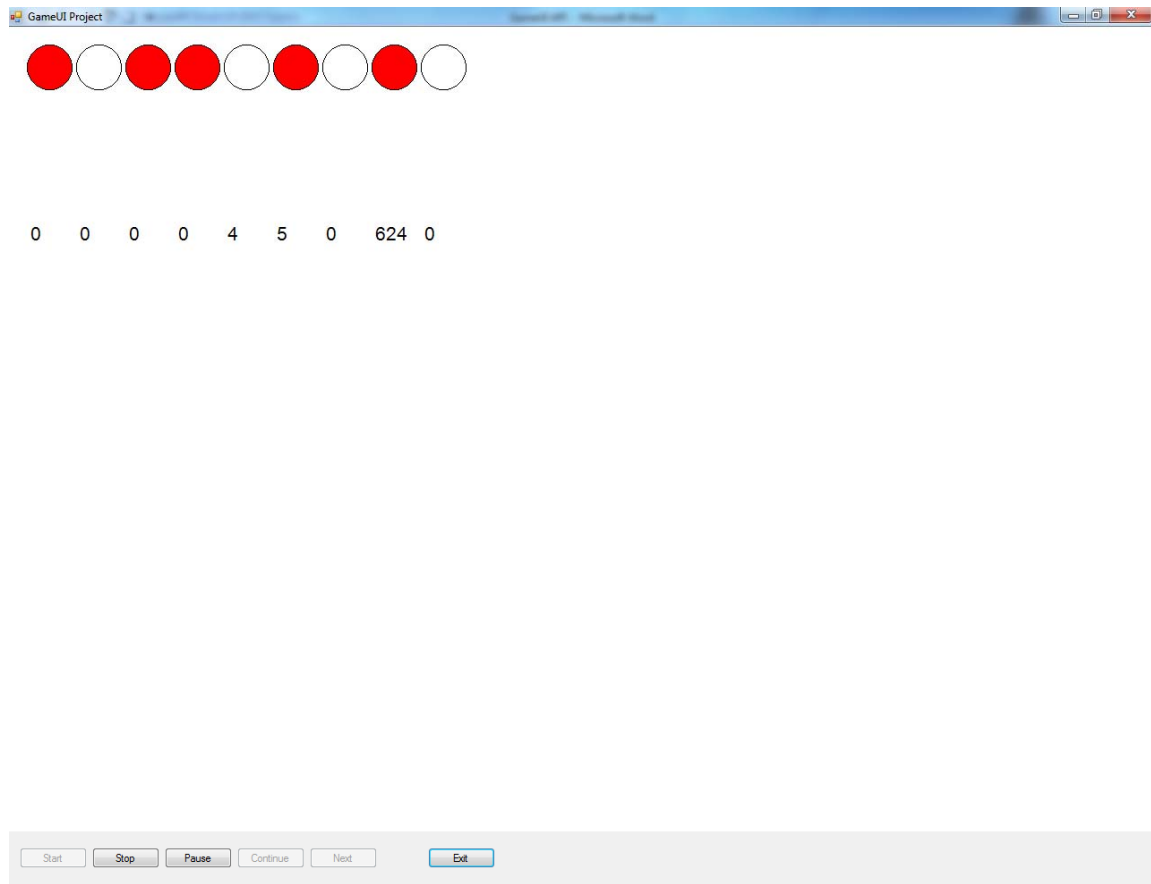


Figure 2.GameUI System

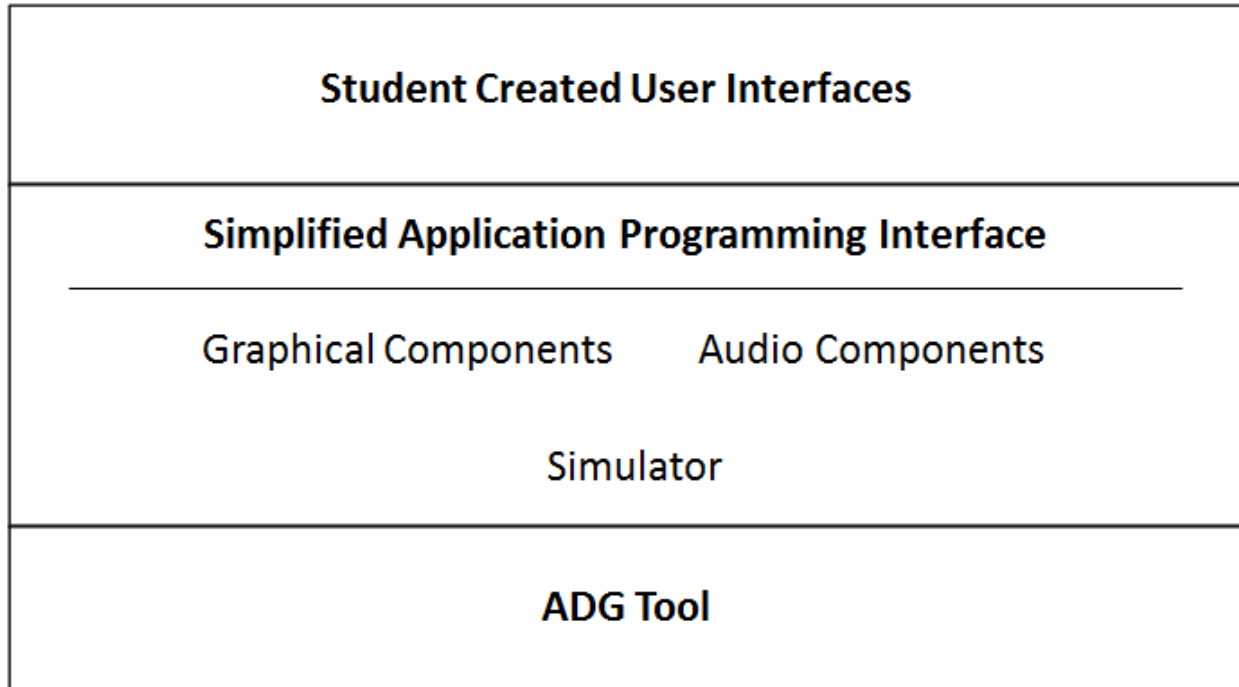


Figure 3. Architecture of GameUI System

Risks

Below are the risks and the actions taken, to reduce their effect on the usefulness of the assignment.

- Students did not have prior experience with C#. This was mitigated by the fact that all students would have been taught C++ and so the required object-oriented concepts would be known.
- The addition of another assignment may frustrate students due to the reduced time for the other assignments. Any negative effects were mitigated by keeping the required coding to a minimum.
- Given that two user interfaces were to be developed, the time needed may be too short. As the focus was on the design and not the implementation, considerably little coding would be required with most of the effort being in the creation of the graphics and the audio clips.

Methodology

The revised universal design assignment was given in semester I of the academic year 2013-2014, in the second quarter of the semester. Students were given three weeks to complete the assignment. They were divided into groups of 4-5 students each and they remained in those groups for the duration of the semester. On completion of the assignment, each group gave a 10 minute presentation outlining their solutions. Students were required to complete a questionnaire before and after the assignment i.e. pre and post questionnaires. Before the pre-questionnaire was distributed, students were given a short description of what universal design is, its primary purpose with respect to the design of user interfaces, the available design modalities and the issues that need to be considered when designing for specific types of users.

The pre-questionnaire was divided into two sections. The first section consisted of five questions covering basic demographic information and included gender, age, level of study, current major and registration status (full-time versus part-time). The next six questions were Likert based questions covering the student's attitude towards universal design.

For the post-questionnaire, the same questions existed but an additional seven Likert based questions, focusing on the usefulness of the actual GameUI software, were added. Two short answer questions focusing on the lessons learned were also included.

Results

The total number of students registered for the course was 37, which was divided into groups of 5 students each, giving a total of 7 groups with two groups containing 6 students each. The total number of respondents for the pre-questionnaire, or pre-test, was 28 (76%) and for the post-questionnaire, or post-test, was 29 (78%). The total number of usable completed questionnaires was 26 for the pre-test (92.9%) and 23 for the post-test (79.3%). A total of 13 males and 13 females responded for the pre-test and 14 males and 9 females for the post-test. For both groups 22 students were full-time. All students in both groups were registered in either the Computer Science or Information Technology majors and all were level III students. Table 1 shows the age ranges for both groups.

Table 1

Age ranges

Age Range	Pre-Test	Post-Test
20-25	21	18
26-29	3	4
30-39	1	1
40-49	1	0

Table 2 contains the results for the questions dealing with students' attitudes towards universal design for both the pre-test and the post-test questionnaires. Each question had 4 possible answers, strongly disagree, disagree, agree and strongly agree. Strongly disagree and disagree have been combined under the heading "Negative Responses" and likewise, strongly agree and agree have been combined under the heading "Positive Responses".

Table 2

Response to questions about attitudes

Question	Negative Responses (Disagree Combined)		Positive Responses (Agree Combined)	
	Pre-Test %	Post-Test %	Pre-Test %	Post-Test %
i. I believe that universal design should be employed by all programmers.	19.2	0	80.8	100
ii. I appreciate the need for universal design during the creation of computer software.	7.8	4.3	92.2	95.7
iii. I believe that universal design should be included in all Human-Computer Interaction courses.	15.4	0	84.6	100
iv. I am confident in my ability to use universal design techniques.	46.2	43.5	53.8	56.5
v. I believe that universal design should be required for the final major project.	46.2	30.4	53.8	69.6
vi. I believe that universal design should not be required for all software development.	73.1	87	26.9	13

As the results indicate, student attitudes towards universal design were positive before the assignment and remained positive on completion of the assignment, increasing in all cases. The most dramatic increases occurred for question (i) and (iii) where the negative responses dropped

to 0. The improved results for question (vi) support the results for (i). These indicate that students see the importance of including universal design topics in an HCI course and including it as part of the software design process.

These results indicate that the students' view of the importance of universal design was not negatively affected by the addition of the assignment. In fact, their positive view increased after the assignment.

To confirm that students truly understood the importance of universal design, the results of the two questions dealing with the lessons learnt are summarized as follows.

- i. What lessons did you learn?
 - Students note that universal design is difficult to implement especially when considering users with physical disabilities.
 - When using universal design, a lot of thought and effort must be made.
 - One common comment was that it is difficult to place yourself in the position of a blind person.
 - Also noted was the importance of maintaining focus on the needs of the user at all times i.e. the needs of the user comes first.

In summary, at the end of the universal design assignment, students understood the difficulties involved with designing software for users with varying abilities. They also began to show an awareness of why the user is central to the development of user interfaces. Finally, they realized that a lot of prior planning is needed to use universal design during the creation of user interfaces.

- ii. Where there any differences between creating a user interface for sighted users versus blind users?
 - Due to their prior experience it was easier to design the user interface for the sighted user than the blind user.
 - The use of audio requires the data to be presented differently such as the use of audio cues versus the global view that can be obtained from visuals. Student soon realized that different approaches are needed when using graphics to display summaries of data versus using audio.

Again the answers to this question demonstrate that students began to understand that designing for users with traits that differ from their own is difficult. Also, the use of programming components other than graphical components requires a different approach than what they are used to.

GameUI Project Results

As in previous years, all groups were unable to complete the entire assignment. In this case, completion was considered to be two running demonstration programs using graphics and audio respectively. Therefore the simplification of the application programming interfaces (APIs) did not produce better results in terms of completion. Students were able to complete designs for the interface for sighted users but not for the blind users. This was a result of the unfamiliarity with the creation and use of audio clips. Also, many students underestimated the time needed to create

audio clips, leaving them to the last minute. However, students were still able to present their ideas for both user interface types.

While students did not have problems using the C# programming language, many found the time to learn the new API too short. As they were able to grasp the C# quickly, it is unlikely that this issue would have been different if the language used was the familiar C++.

Major Project Results

Table 3 contains the grade results for the major project. As can be seen, there were no failures recorded for the last three years, which is the time that the universal design assignments were used. In the last two years, all major projects received an A grade. From these results, it can be seen that the introduction of this new assignment did not affect student performance for the major project. This assignment was worth 10% of the final course mark. The average was 7.94% in both the 2012-2013 and 2013-2014 academic years.

In summary, there was no improvement in the overall performance of the students for the major project. However, the high standards were maintained.

Table 3

Implementation grades for major project

Year	A	B	C	D	F
2008-2009	66.7% (4)	16.7% (1)	16.7% (1)		
2009-2010	20% (1)	40% (2)	20% (1)		20% (1)
2010-2011	20% (1)	40% (2)	20% (1)		20% (1)
2011-2012	50% (4)	25% (2)		25% (2)	
2012-2013	100% (7)				
2013-2014	100% (7)				

Overall Course Results

Table 4 shows the overall coursework marks for all of the years the HCI course has been offered. The coursework forms 40% of the overall course mark and the final examination accounts for the remaining 60%. The table shows that the total enrollment for the course has been steadily increasing. Also, the performance has increased steadily with the year 2010-2011 being the worse in terms of the number of As and 2008-2009 in terms of the number of Ds and Fs. Tables 5 and 6 show the overall final course results and demonstrates steady improvements over the years. The most significant improvements occurred in the coursework marks and can be attributed to the improvements gained in the major project.

Table 5 shows a decline in performance between the academic years 2012-2013 and 2013-2014. This is a result of more students getting above 34% in the coursework in 2012-2013 than 2013-2014. However, table 5 shows that students performed better in the final exam in 2013-2014 resulting in a near equal overall performance in both years. It should also be noted that in 2013-2014, all students passed the course (see table 6).

In summary, the introduction of the new assignment in 2013-2014 did not affect the overall performance of students when compared to the previous years.

Table 4

Overall coursework marks

Year	A	B	C	D	F	Total
2008-2009	55.6% (10)	33.3% (6)	0	5.6% (1)	5.6% (1)	18
2009-2010	81.8% (18)	13.7% (3)	4.5% (1)			22
2010-2011	42.9% (9)	52.4% (11)	4.8% (1)			21
2011-2012	89.7% (35)	7.7% (3)	2.6% (1)			39
2012-2013	100% (37)					37
2013-2014	100% (37)					37

Table 5

Coursework, final exam and total marks averages

Year	Coursework (40)	Final Exam (60)	Overall (100)
2008-2009	24.3	31.1	55.3
2009-2010	29.7	29.5	59.2
2010-2011	26	36.2	62.2
2011-2012	30.9	32.5	64.4
2012-2013	32.6	33.1	65.8
2013-2014	31.1	34.4	65.4

Table 6

Overall course grades (includes coursework and final exam)

Year	A	B	C	D	F
2008-2009	33.3% (6)	33.3% (6)	27.8% (5)	0	5.6 % (1)
2009-2010	28.5% (6)	38.1% (8)	28.6% (6)	0	4.8% (1)
2010-2011	33.3% (7)	42.9% (9)	23.8% (5)	0	0
2011-2012	43.6% (17)	28.2% (11)	23.1% (9)	0	5.1% (2)
2012-2013	43.2% (16)	51.4% (19)	2.7% (1)	0	2.7% (1)
2013-2014	43.2% (16)	43.2% (16)	13.5% (5)	0	0

Universal Design Question

In the 2011-2012 and 2013-2014 final exams there was a question on universal design. In both cases, the first half of the question dealt with simple recall about what is universal design and the principles of universal design. The second half dealt with its application in specific circumstances such as for visually impaired users.

In 2011-2012, 16 out of 39 (41.03%) students attempted the question and in 2013-2014, it was 30 out of 37 (81.08%). The average mark out of a possible total of 15 was 10.75 in 2011-2012 and 11.37 in 2013-2014.

In the 2013-2014 year, students demonstrated a greater understanding of the concept of universal design. They were better able to discuss the specific software changes needed to handle as large a range of users as possible. In some cases, students were able to go beyond what was in the notes, basing some of their answers on their own experience in the course assignments.

The increase in the number of students answering the question indicates some increased measure of confidence in the topic. This shows that there is a possible correlation between the use of the new assignment and the increased confidence. There may also be a relationship between the increased positive attitude and increased willingness to answer this question.

Discussion

Utilizing the results of the previous section, the three research questions can now be considered.

1. *Can an intervention focused on universal design increase students' appreciation for the area?*

Table 2 demonstrates that students' appreciation for universal design became more positive for every question. Students demonstrated a greater awareness for the importance of universal design in both the teaching of HCI and within the commercial development of any software application. The written comments of the students also support their answers for the Likert-based questions.

2. *Would inclusion of an extra assignment depreciate students' appreciation for the topic of universal design?*

The introduction of this assignment did increase the coursework load of the students and as a result their completion rate did not improve. However, it did not affect their appreciation of the topic as shown in table 2. Also, as discussed before, more students attempted the universal design question in the final exam than in previous years. They also performed better.

3. *What effect would the inclusion of this assignment have on students' performance in the final major project?*

As the results in tables 3 to 6 show, the performance of the students did not decline. In some cases, there were improvements over the previous years, such as the improvement in the final examination and failure rates. Table 3 shows the results for the final major project and they remain unchanged from the previous year, which was the best year during the course's entire existence.

Conclusion

The results demonstrate that with the introduction of the universal design topic as the first assignment, student performance in the major project, coursework and final exam did not suffer and, improved in some cases. Providing students with the opportunity to make comparisons for the two user groups enabled them to understand the difficulties involved with designing user interfaces for a wide range of user types. This in turn demonstrated to them the importance of understanding the various universal design theory and techniques.

The small improvements between the last two years indicate that the introduction of the new universal design assignment did not affect the performance improvements achieved over the years. The written comments by the students in the last year show that students were able to grasp and maintain their understanding of the need for universal design. This was supported by the results for the questionnaire which show small improvements in students' positive attitudes towards universal design.

One area of concern is the students' inability to complete the assignments and produce functional prototypes. In the future, the assignment will be adjusted to one where the prototypes are not necessary and only the overall user interface design will be required. In this case, the GameUI tool will be for reference and testing of ideas purposes only. This fits in well with what occurred over the last three years of the course.

References

- ACM SIGCHI Curricula for Human Computer Interaction. (n.d.). Retrieved September 2, 2014 from <http://old.sigchi.org/cdg/>
- Basham, J. D., & Marino, M. T. (2013). Understanding STEM Education and Supporting Students Through Universal Design for Learning. *Teaching Exceptional Children*, 45, 8-15. March/April 2013, 45(4), 8-15.
- Becker, S. A. (2004). A study of web usability for older adults seeking online health resources. *ACM Transactions on Computer-Human Interaction*, 11(4), 387-406.doi: 10.1145/1035575.1035578
- Bjork, E. (2009). Many become losers when the Universal Design perspective is neglected: Exploring the true cost of ignoring Universal Design principles. *Technology and Disability*, 21, 117-125.doi: 10.3233/TAD-2009-0286
- Carroll, J. M., & Rosson, M. B. (2005). A case library for teaching usability engineering: design rationale, development, and classroom experience. *ACM Journal on Educational Resources in Computing*, 5(1), Article 3.doi: 10.1145/1101670.1101673
- Coppit, D. (2006). Implementing large projects in software engineering courses. *Computer Science Education*, 16(1), 53-73.
- Dix, A., Finlay, J., Abowd, G. D., & Beale, R. (2004). *Human-Computer Interaction*. Prentice Hall, 3rd Edition, 2004.
- Hochheiser, H., & Lazar, J. (2010). Revisiting breadth vs. depth in menu structures for blind users of screen readers. *Interacting with Computers*, 22, 389-398.
- Inkpen, K. M. (2001). Drag-and-drop versus point-and-click mouse interaction styles for children. *ACM Transactions on Computer-Human Interaction*, 8(1), 1-33.doi: 10.1145/371127.371146
- Liffick, B. W. (2005). An adaptive technologies course in a CS curriculum. *Proceedings of the 7th international ACM SIGACCESS Conference on Computers and Accessibility*, 192-193.doi: 10.1145/1090785.1090825
- Lombardi, A. R., & Murray, C. (2011). Measuring university faculty attitudes toward disability: Willingness to accommodate and adopt universal design principles. *Journal of Vocational Rehabilitation*, 34, 43-56.doi:10.3233/JVR-2010-0533
- McCrickard, D. S., Chewar, C. M., & Somervell, J. (2004). Design, science, and engineering topics? Teaching HCI with a unified method. *Proceedings of the 35th SIGCSE Technical Symposium on Computer Science Education (SIGCSE'04)*, 31-35.doi: 10.1145/971300.971314
- Microsoft, .NET Framework and .NET SDKs.(n.d.).Retrieved September 2, 2014 from <http://msdn.microsoft.com/en-us/vstudio/aa496123>
- Microsoft, C# Fundamentals for Absolute Beginners. (n.d.). Retrieved September 2, 2014 from <http://channel9.msdn.com/Series/C-Fundamentals-for-Absolute-Beginners>
- Microsoft, C++ Language Reference. (n.d.). Retrieved September 2, 2014 from <http://msdn.microsoft.com/en-us/library/3bstk3k5.aspx>

- Obrenovic, Z., Abascal, J., & Starcevic, D. (2007). Universal accessibility as a multimodal design issue: Creating adaptable solutions to address diverse users and situations, *Communications of the ACM*, May 2007, 50(5), pp 83-88. doi: 10.1145/1230819.1241668
- Oracle Technology Network: Java.(n.d.). Retrieved September 2, 2014 from <http://www.oracle.com/technetwork/java/index.html>
- Poor, G. M., Leventhal, L. M., Barnes, J., Hutchings, D. R., Albee, P., & Campbell, L. (2012). No User left behind: Including accessibility in student projects and the impact on CS students' attitudes. *ACM Transactions on Computer Education*, 12(2), Article 5. doi: 10.1145/2160547.2160548
- Rivera-Nivar, M., & Pomales-Garcia, C. (2010). E-training: Can young and older users be accommodated with the same interface? *Computers & Education*, 55, 949–960. doi:10.1016/j.compedu.2010.04.006
- Sapp, W. (2009). Universal Design: Online Educational Media for Students with Disabilities. *Journal of Visual Impairment & Blindness*, 495-500.
- Sayagoa, S., & Blat, J. (2010). Telling the story of older people e-mailing: An ethnographical study. *International Journal of Human-Computer Studies*, 68, 105–120.
- Shneiderman, B., & Plaisant, C. (2005). *Designing the User Interface: Strategies for Effective Human-Computer Interaction*. Addison Wesley, 4th Edition.
- Siu, K. W. M. (2011). Public Toilets for Visually Impaired Persons: Application of the Principles of Universal Design. *The International Journal of Interdisciplinary Social Sciences*, 6(2), 117-126.
- Smith, G., Vega, L. C., & McCrickard, D. S. (2008). Education and design: using human-computer interaction case studies to learn. *Proceedings of the 46th Annual Southeast Regional Conference on XX (ACM-SE'08)*, 346-351. doi: 10.1145/1593105.1593197
- Story, M. F., Mueller, J. L., & Mace, R. L. (1999). The universal design file: Designing for people of all ages and abilities. Retrieved September 2, 2014 from http://www.ncsu.edu/ncsu/design/cud/pubs_pp/pudfiletoc.htm
- Takagi, H., Saito, S., Fukuda, K., & Asakawa, C. (2007). Analysis of navigability of web applications for improving blind usability. *ACM Transactions on Computer-Human Interaction*, 14(3), Article 13. doi: 10.1145/1279700.1279703
- Udo, J.P., & Fels, D.I. (2010). The rogue poster-children of universal design: closed captioning and audio description. *Journal of Engineering Design*, 21(2-3), 207–221. doi: 10.1080/09544820903310691
- Waller, A., Hanson, V. L., & Sloan, D. (2009). Including accessibility within and beyond undergraduate computing courses. *Proceedings of the 11th International ACM SIGACCESS Conference on Computers and Accessibility*, 155-162. doi: 10.1145/1639642.1639670
- Whiddett, R. J., Jackson, B. X., & Handy, J. A. (2000). Teaching information systems management skills: using integrated projects and case studies. *Computer Science Education*, 10(2), 165–177.
- Yesilada, Y., Stevens, R., Harper, S., & Goble, C. (2007). Evaluating DANTE: Semantic Transcoding for Visually Disabled Users. *ACM Transactions on Computer-Human Interaction*, 14(3), Article 14. doi: 10.1145/1279700.1279704.

