Assistive Technology for the Visually Impaired

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# ABSTRACT

Digital media is becoming much more than a supplement in the field of educational technology. Online books, journals, collaboration, and even graduate degrees can be obtained exclusively through digital resources. Indeed, pedagogy has kept pace with advances in digital technology, and for most, the educational experience has been enhanced. However, for those with a visual impairment, the ability to travel unabated in a digital world is rife with restrictions that limit access to information and educational enrichment. Although assistive technologies such as screen readers (text to speech), magnifiers, and high contrast settings allow the visually impaired to ride this information superhighway, these tools are often difficult for the visually impaired to identify, locate, and administer. Even when configured, there are many differences in how assistive technologies are implemented. The current state of assistive technology is not progressive enough for alleviating the challenges and inconsistencies the visually impaired face when accessing digital media. Introducing standard(s) for assistive technology would remove barriers to digital media, and open this autobahn to the visually impaired. Another approach to convey visual information is to utilize a second sensory input. A technology known as auditory graphing, which is an application of sonification [3] shows promise as an assistive technology to enhance learning in geometry, which is a completely visual form of mathematics [7]. Sonification uses sound: frequency, amplitude and timbre to convey information. Auditory graphs can increase accessibility by allowing observable objects such as curves in a Euclidian plane can be visualized. Sonification and standardization of assistive technology are tractable, cost effective approaches to enhance pedagogy for the visually impaired.

Author Keywords

Accessibility, assistive technology; auditory graphing; digital media; educational technology; sonification; standards; special needs, visual impairment.

ACM Classification Keywords

Human-centered computing---Human computer interaction (HCI)---HCI design and evaluation methods;500, Human-centered computing---Human computer interaction (HCI)---Interaction paradigms---Graphical user interfaces;500, Human-centered computing---Human computer interaction (HCI)---Interaction paradigms---Web-based interaction;300, Human-centered computing---Human computer interaction (HCI)---Interaction devices---Displays and imagers;500, Human-centered computing---Human computer interaction (HCI)---Interaction devices---Sound-based input / output;500, Human-centered computing---Human computer interaction (HCI)---Interaction techniques---Auditory feedback;500.

**INTRODUCTION**

The world of digital media is vast and seemingly unbounded. However, for the visually impaired, it can be narrow and challenging to explore. In the context of this paper, visually impaired will refer to individuals with low vision that require special needs. According to the National Eye Institute, “low vision means that even with regular glasses, contact lenses, and medicine or surgery, people find everyday tasks difficult to do.

Education has become increasingly digitized. Research [4] presented in Table 1 shows that teachers (K-12) are heavy users of digital content in the classroom. Driving this shift to a digital pedagogy is the faith that society places on the inherent power of digital media to enhance teaching and learning practices [12]. Indeed, society has driven electronic media in education, as policymakers have enacted laws [13, 14] supporting technology in the classroom. If this digital content is not accessible to the visually impaired, then a significant portion of their education is unapproachable.

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| --- | --- | --- | --- | --- | --- |
| % | Videos Found Online | Real Time Data | Online Textbook | Anima-tion | Virtual Labs |
| All | 48 | 18 | 27 | 22 | 9 |
| Sci | 63 | 32 | 32 | 52 | 42 |

Table 1: Teachers’ Use of Digital Content in the Classroom.

A very effective assistive technology for those with low vision are High Contrast Settings (HCS) available on most operating systems (OS), and applications such as Adobe Reader and various web browsers. HCS is freely available, both in cost and distribution, and will be the focus of my research. Fok, et al. [2] show that Adaptive Computer Technologies (ADT) such as HCS are used by 57.7% of their sample group. Although this seems high, the utilization of HCS can be expanded if this technology was standardized across platforms and applications. Phillips and Zhao [6] identified the ease of device procurement, and poor device performance as reasons why users disregard assistive technology. Although the scope of assistive devices in [6] is much larger, and includes physical aides such canes and wheelchairs, the rational for user abandonment can be extrapolated to ADTs. For example, ‘device procurement’ can be translated to identifying and configuring HCS. Standardization of ADTs can abate procurement challenges while greatly improving the performance of HCS. Beyond abandonment, procurement challenges have a more impact on the usage of ADTs. Kapperman, et al. [11] discuss how the lack of technical knowledge by both educator and student limit the use of ADTs to less than half the students with visual impairments who could potentially benefit from assistive technology. Another approach is to provide a second (non-visual) modality to enhance pedagogy for the visually impaired. Auditory graphs using sonification provides an auricular method for the visually impaired to experience mathematics.

**DISCUSSION OF PROBLEM**

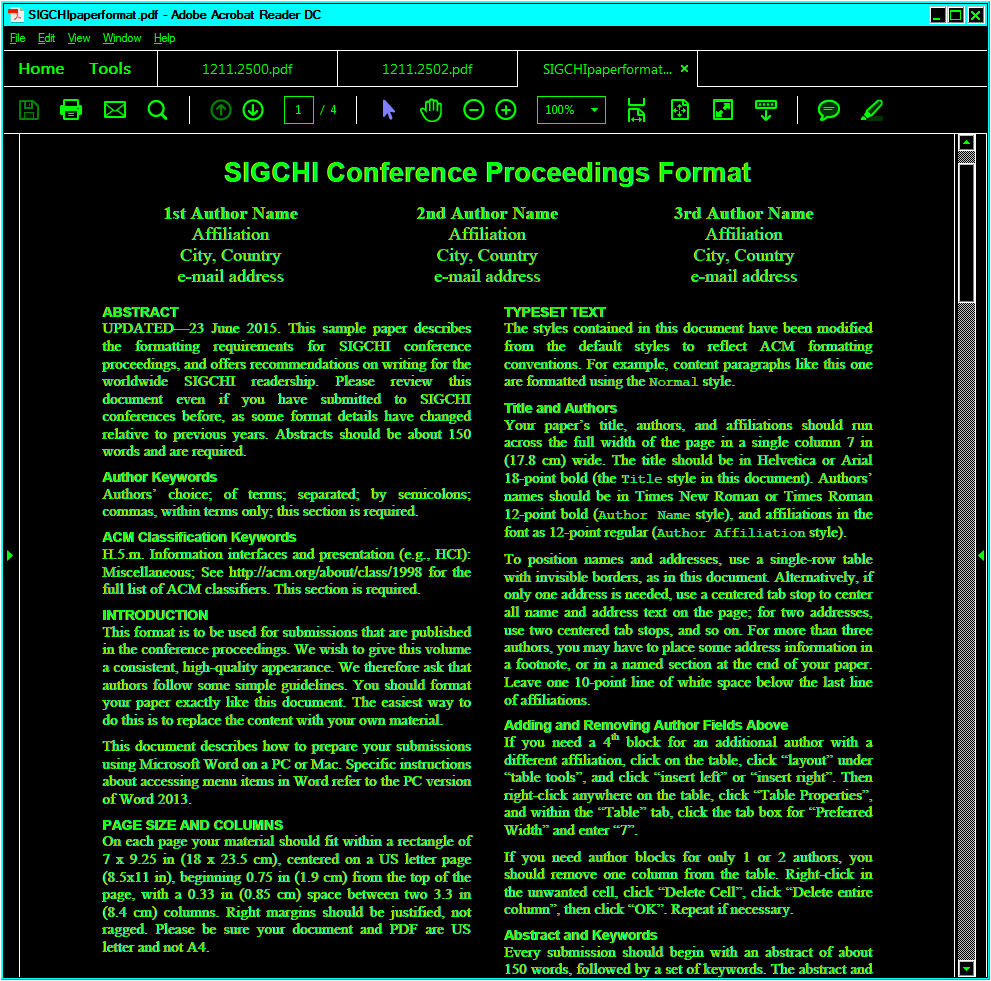
In most cases, ADT and HCS grant the visually impaired access to digital media. However, at times, the user experience is inconsistent, and often dysfunctional. This discussion will explore issues faced by visually impaired when accessing standard contrast digital media and limitations the current state of HCS.

**Light reading**

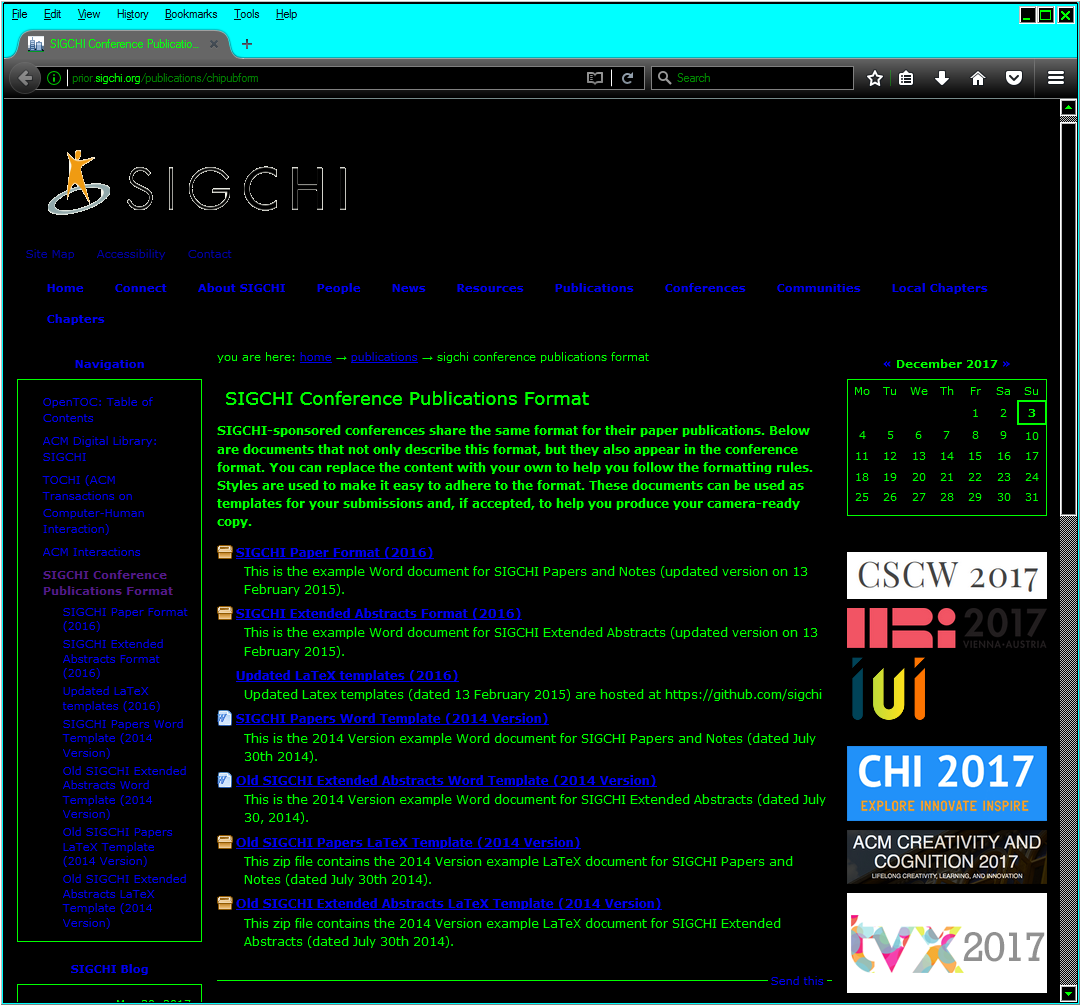
Persons who are visually impaired due to retinal issues can benefit from HCS. Light of a sufficiently high intensity will compromise visual acuity in persons having conditions that affect the retina, such as: macular degeneration, diabetic retinopathy and even age. In persons without a visual impairment, visual acuity has a well-defined relationship with illumination. That is, visual acuity increases in proportion to the log of the light intensity [10]. The retina is a surface composed of discrete rods and cones, therefore its resolving power depends on the number of elements present in a unit area [10]. In persons with a compromised retina, this unit area is decreased, thus decreasing the amount of illumination the retina can process. Even the ubiquitous white (RGB: 255, 255, 255) background used under most standard contrast settings for electronic displays is sufficient to overwhelm the ability to process information for a person with a retinal issue. Consider the retina as analogous to film in a camera. Consider the recent solar eclipse of 2017 that crossed the USA. Aside from potential sensor damage, filming a partial solar eclipse without proper filtration on the camera would not produce a viable image. The intensity of an eclipse not in totality would inundate the sensor, creating at best a very noisy image.

**High contrast settings**

High contrast is defined as a large difference in magnitude and gradient between colors in an image. In the context of this paper HCS will refer to the difference in magnitude between the background, which typically constitutes the majority of the display area (>> 50%), and foreground (text, images, etc.) in digital media.

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**Figure 1**: Windows high contrast theme, MS Word (left). Adobe Reader with high contrast colors (right).

**Figure 2**: Web browsers with high contrast: Internet Explorer (left), Mozilla Firefox (center), Google Chrome (right).

The images in Figures 1 and 2 show the HCS available embedded with the OS (High contrast theme on Windows) or application (Adobe Reader, Google Chrome, Mozilla Firefox). It should be noted that the high contrast theme on Windows not only supports Microsoft applications: Word, Excel, PowerPoint, etc., but also Mozilla Firefox. Google Chrome and Adobe Reader are not natively supported by Windows, and must be configured for HCS separately. These examples show HCS provides a display with a high gradient between the background and foreground. More importantly, the contrast is inverted from the typical setting of light background, dark foreground (text). Recall that a white background has irradiance capable of decreasing acuity for the visually impaired. Therefore, it is important to not only have a high gradient between background and foreground, the background should be dark, ideally RGB [0, 0, 0].

**Where is the high contrast**

The images in Figure 3 show the inconsistent styles of high contrast displays with web browsers.



**Figure 3**: Web browser display results from a query of the string ‘Images for fred flintstone’: Internet Explorer (left), Mozilla Firefox (center), Google Chrome (right).

Each application has (dis)advantages. The text in the search results, and heading in the results using Mozilla Firefox is difficult to read. Internet Explorer does a better job distinguishing the text color used for the results headers, but could apply a lighter color to the search results text for stronger differentiation. Google Chrome’s HCS is superior for applying a high gradient between text and background. However, Chrome falls short in attempting to apply HCS on images (pictures), leading to a strange, negatively colored image. Text and image rendition are not the only shortfalls of web browser HCS. Highlighting (Figure 4), and form input collectionmethods (figure 5) present even more adversity for those using HCS with IE or Firefox. Fundamental attributes of usability, denoting selections are not possible unless HCS is disabled. This phenomenon is difficult to capture for this paper outside the application. That is, how can something that is not visible be depicted? Suffice to say, selections were made using IE in figures 4 and 5, however, the choices were not highlighted in way to make the choice obvious for the user. Google chrome did not have these issues,

but was did not display a uniform dark background on the screen. The lighter colors could present issues for some visually impaired persons. The ideal scenario would have an unbroken dark background with a light colored foreground, including those elements that allow for user selection, such as the fill for radio buttons, tick boxes, etc.

Lastly, some documents viewed using Adobe Reader are not compatible with Reader’s HCS option. These documents will invariable present in standard contrast, signifcanly reducing perception for the visually impaired reader. Perfunctory research indicates that these documents were either created with settings incompatible with Reader’s HCS standards, or scanned in to create a PDF document.

**Inaccessible Accessibility**

The ADTs offered on operating systems and applications are difficult to initially configure for the visually impaired. This discussion will explore the challenges of provisioning HCS at the OS (Windows) and application level.

Although setting up HCS on Windows is a direct procedure, this option remains unknown to many users. HCS is enabled by ‘Personalizing’ the desktop with a High Contrast theme. Once enabled, this setting applies HCS to all Microsoft applications, Mozilla Firefox, but not Google Chrome. As already discussed, Windows HCS performs reasonably well creating a display that allows those with low vision good visual perception of the media.

Adobe Reader’s HCS is not covered under Window’s HCS option, and must be configured separately. To set up HCS for Reader, the user must navigate to the preferences drop-down, and locate HCS in the (sub)tree of options. This path is not obvious, and could be moved to a more direct path for the user.

Like Reader, Google Chrome also lacks support under Window’s HCS. Chrome is perhaps the most challenging application in this study to provision HCS. A user must use the Chrome browser, which is not initially set up for HCS, and navigate to a Google site to download and setup HCS. The entire process is accomplished using standard contrast, which for those with low vision, presents a paradox. That is, a user with low vision experiences very low visual acuity under standard contrast, ???

**METHODOLOGY AND SCOPE**

TBD.

METHODOLOGY: Discuss your research methodology. Did you employ qualitative or quantitative research methods? Did you administer a questionnaire or interview people? Any field research conducted? How did you collect data? Did you utilize other libraries or archives? And so on.

SCOPE: Indicate as soon as possible what you intend to do, and what you are not going to attempt. You may limit the scope of your paper by any number of factors, for example, time, personnel, gender, age, geographic location, nationality, and so on.

**A standard approach for high contrast settings**

TBD.

**Have you heard about sonification**

In addition, sonification will be explored as a potential ADT for enhancing the pedagogy of mathematics for the visually impaired ???

Another ADT that has not been fully exploited is sonification. For this discussion, the term ‘sonification’ refers to the “use of non-speech audio to convey information or perceptualize data” [3]. Chew [1] assessed using auditory graphing systems for visually impaired middle school students in mathematics.

Sonification can increase accessibility by allowing observable objects such as curves in a Euclidian plane can be visualized. Upson [7] discusses using sonification to visualize geometry, which is a completely visual form of mathematics. Upson’s proposes sonification as another vector for assimilating information, and targets middle school pupils. Essentially, using both sight and sound will increase the absorption of the material. Although Upson is not targeting the visually impaired, others [8, 9] have used sonification for this audience.

Studies in the field of ophthalmology have stressed the importance of assistive technology resources, such as learning tools for visually impaired students [5].

**Sonification is not widely deployed**

Sonification as an educational technology is not widely deployed. Upson discusses using sonification [7] for middle school visual mathematics, geometry. This is a narrow topic in a single subject over the pedantic universe. Even more narrow is the visually impaired slice of this audience. Sonification is analogous to orphan drugs, a small market lacks economies of scale. Walker and Cothran [9] explore addition reasons why sonification is not widely used: “few sonification toolkits that have been developed are either proprietary, dependent on a specific hardware or software platform (e.g., SGI/Irix), are not powerful enough, or are built for the expert sonification designer, and not the schoolteacher or student”. I plan to extend the work of Walker and Cothran to include high contrast options in my sonification toolkit. I’d like to study human factors to evaluate sonification and high contrast settings for the visually impaired population.

**RESULTS AND DISCUSSION**

TBD.

**FUTURE WORK**

This section will be developed as the project undergoes further development. For now, it will serve as a reference and guide for additional work. As results, and additional research comes in, the section will expand to accommodate it.

Arrange images to increase size of image.

Add in examples of good HCS applications, Putty, and bad applications HCS: eclipse, Adobe HCS for old documents and images in some Adobe files.

Add in section in discussion describing non-standard approaches to initial set-up of HCS.

**Human Factors Study**

Find additional research on sonification, and game development, as I plan a small proof of concept tool that uses sonification for simple graphs on a 2-dimensional plat. The objective is to host this tool, and have students (both sighted and visually impaired) evaluate it. The toll will count the number of times students enable high contrast and sonification.

Identify additional research that highlights the acceptance and efficacy of ADT for the visually impaired, in particular, high contrast. I would also like to have a counterpoint that shows good usage, but if the high contrast were more standardize, it would have an even greater impact.

Identify resource that show the traditional white background is not usable for the visually impaired. High contrast, in particular, a dark background with light text works best. Some examples from users of Adobe high contrast: <https://forums.adobe.com/thread/777688>

**CONCLUSIONN**

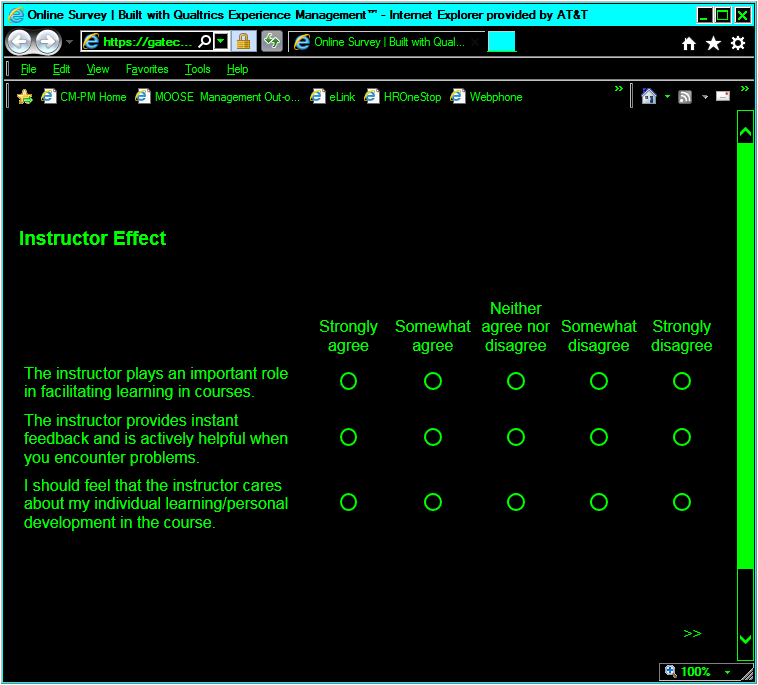
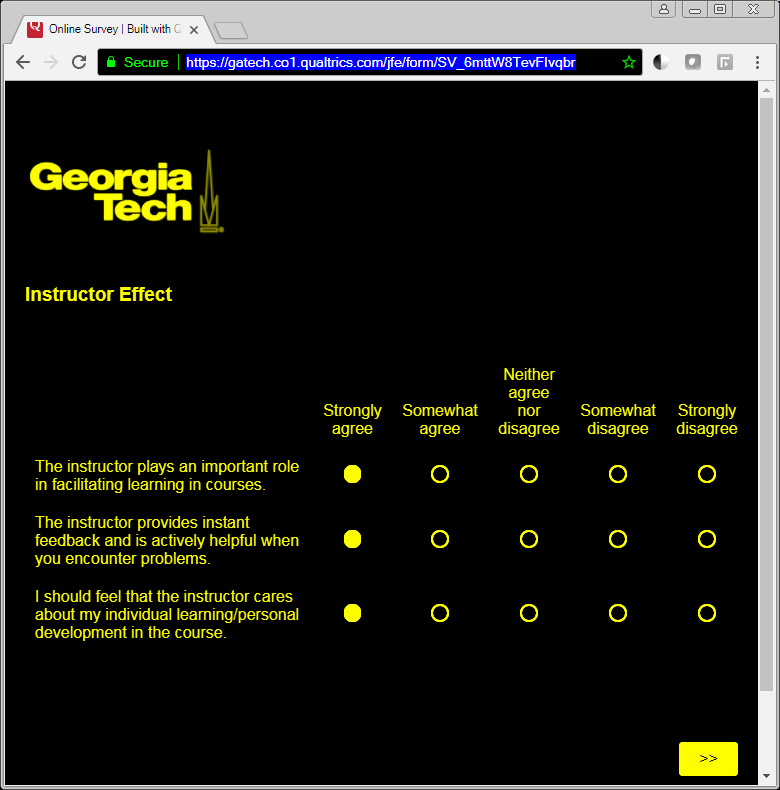
In summary, research has been presented that highlights the need for additional, and a more standardized approach toward assistive technologies for the visually impaired. Moreover, standardization and sonification can fill gaps in existing ADTs, and allow for a more effective and rich educational experience for the visually impaired.

**ACKNOWLEDGEMENTS**

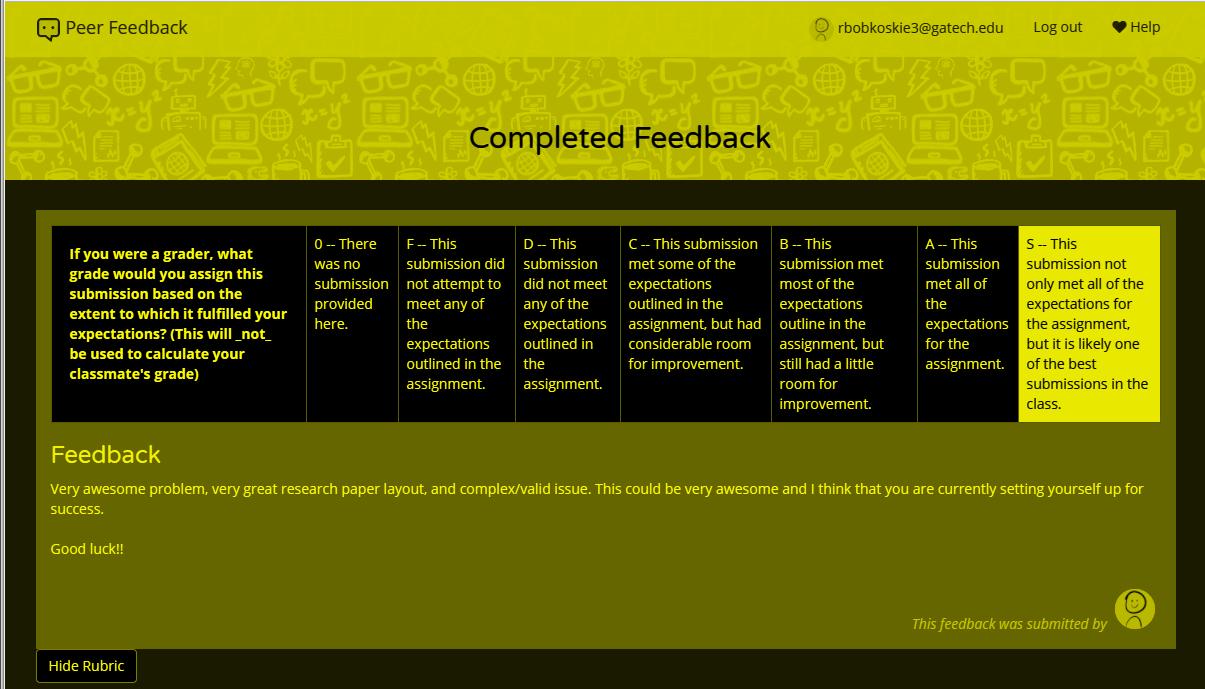
My mentor, Zach Hooks. My cohort who provided invaluable peer feedback throughout this project.

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**Figure 5**: Radio buttons to make selection in web browsers: Internet Explorer (left), Google Chrome (right). The selection of the left most choices using Internet Explorer (IE) was not obvious to the user. Mozilla Firefox, like (IE), makes use of the Windows high contrast theme, looks like IE, and was omitted.

**Figure 4**: Highlighting to make selection in web browsers: Internet Explorer (left), Google Chrome (right). The selection of the right most choice using Internet Explorer (IE) was not obvious to the user. Mozilla Firefox, like (IE), makes use of the Windows high contrast theme, looks like IE, and was omitted.