The Impact of Curriculum Visualization on Decision Making Among Students

An Honors Thesis (HONRS 499)

By

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Abstract

Working with course catalogs, the DAPR system, the course shopping cart, and the course request system is confusing for most students. With these resources it is difficult for students to make good decisions about which courses to enroll in, the order in which to take a sequence of courses, which minor to choose, and to which major or option to switch. CurricVis is a system that utilizes curriculum visualizations to help students build more accurate mental models of curricular programs, allowing them to make more informed curricular decisions.

The purpose of the study was to measure the effects a curriculum visualization tool has on students' abilities to make decisions. We compared those findings with the effects of using only traditional, text-based curricular data. The hypotheses tested in this study were: students build more feasible plans with the aid of the curriculum visualization tool; students are more confident about their decisions with the tool; and students make their decisions more quickly with the tool. This study shows that CurricVis functions as a positive aid to the decision making process among students. No other research on curriculum visualization has included such a study on usability.

Acknowledgements

I would like to thank Dr. Paul Gestwicki for advising me through this project. We have been working on this research since Fall of 2008, and his guidance has been invaluable.

I would also like to thank fellow students who have helped me with various parts of the study: Gunnar Hoffman, Jordan Turpen, Andrew Haddad, and Grace Perdew.
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1. **Introduction**

Text-based systems for describing curricula are often inadequate for helping students make curricular decisions. Course catalogs, degree progress reports, and online course request systems do not readily help students understand the overall "shape" of their programs [1]. To address this problem, Dr. Gestwicki and I researched the effects of visualization techniques on students' curricular understanding by creating CurricVis, a tool that implements curriculum visualization. Curriculum visualization is the application of information visualization techniques to curricular data [1, 2]. CurricVis was designed to assist students, curriculum designers, advisors and administrators in communicating and reasoning about curricula. We developed three hypotheses for this research.

H1: Curriculum visualization techniques help students make tough choices about curricula more confidently than text-based modes.

H2: Students using curriculum visualization tools are more accurate than students using text-based tools.

H3: Students are able to solve curricular problems more quickly with the aid of curriculum visualization tools than with text-based tools.

The research encompassed four stages: formalization, design, implementation, and usability testing. In the formalization stage we analyzed interdepartmental differences in curriculum description to compose a taxonomy of requisites. We ultimately found that the requisites of academic programs we studied can be divided into one of three general types: prerequisites, corequisites, or antirequisites. Prerequisites are courses that must be completed before another course can be taken. Corequisites are courses that must be taken at the same time as another course. Antirequisites affect the availability of a course in the opposite direction; if the antirequisite of course A has been taken, then the student cannot enroll in course A. More complicated relationships between courses are composites of these three basic relationships (an example is described below).

The requisite taxonomy was then used to create a formalized model for curricular description, which I translated into the domain-specific language that CurricVis uses to define curricula. The requisite description of Ball State's CS300 course is an interesting example of this model and language at work. To enroll in CS300, a student must take CS120 or CS203 or CS233 as parallel courses. In the model, a parallel course is a composite of a prerequisite and a corequisite. The language uses the ANDOR relationship to define such complicated requisite structures:

\[
\text{andor}(1, \text{pre(CS120)}, \text{co(CS120)})
\]
The first parameter indicates that one of the following parameters must be fulfilled for this relationship to be fulfilled, making this an OR relationship. If the 1 is replaced with a 2, it becomes an AND relationship (since there are only two parameters). The entire requisite structure for CS300 is modeled as

\[
\text{andor}(1, \text{andor}(1, \text{pre}(\text{CS120}), \text{co}(\text{CS120})), \text{andor}(1, \text{pre}(\text{CS203}), \text{co}(\text{CS203})), \text{andor}(1, \text{pre}(\text{CS233}), \text{co}(\text{CS233}))).
\]

Fortunately, this particular relationship can be simplified to \(\text{andor}(1, \text{pre}(\text{CS120}), \text{co}(\text{CS120}), \text{pre}(\text{CS203}), \text{co}(\text{CS203}), \text{pre}(\text{CS233}), \text{co}(\text{CS233}))\), but such an easy simplification is not always possible.

The design stage involved several prototyping iterations (paper and electronic) to ensure that each aspect of the interface would contribute to the user's mental model of the data. Node-link diagrams are used to describe relationships among courses in an academic program. A progress bar attached to each diagram displays the student's progress in the program. To facilitate curricular planning, CurricVis employs a "hypothetical" system that allows students to mark courses as hypothetically complete. Hypothetical mode helps students visualize the effects of their curricular decisions. The progress bars distinguish between real and hypothetical progress, and a separate view displays the progress bar of each program in which the student has made progress. This view is especially useful for students still exploring programs.

**Figure 1: Node Link Diagram of CS Major**

Black ellipses represent completed courses, green indicates available courses, and orange courses are "hypothetically complete" courses.
This paper focuses on the usability testing stage. I gained IRB approval and designed the evaluation tools for usability testing, which involved splitting 32 volunteers into a control group (using traditional resources) and an experimental group (using CurricVis). The groups completed tasks based on typical problems students face when dealing with curricula. The subjects were measured for the level of confidence they had in their answers (H1), accuracy in their answer (H2), and speed in task completion (H3). We also measured the perceived difficulty of each task with a five point Likert scale. We hypothesized that subjects in the experimental group would score higher in each of the three categories than subjects in the control group, and that experimental subjects would find the tasks less difficult.

The development of a tool that integrates useful, interactive visualizations of curricula with a curricular knowledge base is a significant contribution to information visualization. This work leads to insights into the development of interactive visualizations for complex systems and the integration of usability analysis with information visualization research. The ultimate goal of this work is to make the software and techniques we develop available to any institution. “Visualizations can lead to improved communication, better decision-making by students and planners, and insight into patterns and conflicts” [1]. Using CurricVis to represent curricula would reduce the current cost of supporting curricular reasoning among students, curriculum designers, advisors, and administrators by improving the efficacy of advising in higher education.

2. Methodology
The Curriculum Visualization research team conducted an onsite usability test in RB369 of the Robert Bell Building on Ball State University’s campus during the spring 2010 semester. The primary purpose of the test was to measure the effects a curriculum visualization tool has on students’ abilities to make curricular decisions. The test was also
used to study the usability of CurricVis, a system that utilizes curriculum visualizations to help students build more accurate mental models of academic programs.

**Rounds**

In each round of testing, the participants were split into a control group and an experimental group. In the first round, subjects in the control group were given a course catalog, a copy of a freshman computer science major Degree Analysis Progress Report (DAPR), and access to Ball State’s online course descriptions and “course shopping cart.” Subjects in the experimental group had the same tools, but were also permitted to use CurricVis.

In the second round of testing, we took away access to Ball State’s online course descriptions because the website had been updated to the next year’s catalog, causing unnecessary confusion for the subjects. We also changed the format of the experimental group for the second round of testing: we instructed them to only use CurricVis. In the first round there were a few subjects in the experimental group who never attempted to use the software, claiming to prefer the methods they were familiar with. Obviously that distorted their results, and since the purpose of the study was to measure the efficacy of curriculum visualization techniques, we restricted the use of other methods.

**Participants**

All participants were undergraduate students of Ball State University and had never previously considered a major in computer science. Twenty-two subjects participated in the first round of testing, which took place between the 22nd and 24th of February 2010, eleven each in the experimental and control groups. Eleven subjects participated in our second round of testing between the seventh and 14th of April 2010, five in the experimental group and six in the control group.

**Sessions**

Subjects were recruited through an email sent to the Ball State student body. Students interested in participating responded to the email and were directed to a Google Form to sign up for a time to be tested. Each session lasted approximately twenty minutes. The proctor script was read to the subjects before the start of the test, and subjects were presented the study description sheet. Then the subjects were instructed to complete a series of three tasks. Two to three test administrators were present for each session, which consisted of one to four subjects per session. The test administrators also acted as data loggers, monitoring each subject’s navigational choices, task completion times, comments, questions, and feedback.

After the tasks were finished, the participants completed a brief questionnaire that asked them to rate their confidence in their answers and the perceived difficulty of each task on a 5-point Likert Scale ranging from not confident/difficult to very confident/simple. Next,
the subjects were asked to write out any comments they had on the overall experience. Finally, the proctor asked specific questions about the subject’s behavior during the test (e.g. “Was there a specific reason you chose not to use the course catalog,” and “What did you think when you first saw the diagram for the minor in mathematics?”).

**Evaluation Tasks/Scenarios**
The tasks presented to the first and second groups of participants differ slightly. In the first round of testing, subjects were asked to act as freshmen computer science majors and to complete the following tasks:

1. You are a freshman who has decided to major in computer science, computer science option. Pick the major-specific classes you would take for your first three semesters.
2. Your friends have been talking about their minors and you feel like you should add one to strengthen your resume. Choose a minor from the following list of minors: Minor in Applied Physics option 1 – Electronics; Minor in applied physics option 2 – Nanoscience; Minor in chemistry; Minor in Biology; Minor in Astronomy; Minor in Physics; Minor in Computational Mathematics; Minor in mathematics. Please explain the decision making process that led you to your choice.
3. What are all of the Computer Science courses you have to take to be able to enroll in CS457?

In the second round of testing, subjects were asked to act as sophomore computer science majors and were given a list of courses they had already “completed.” The first task in this second group instructed them to choose the courses they would register for in their next three semesters of school. The second and third tasks were identical in both rounds of testing.

The first task was designed to test a student’s ability to recognize the flow of an academic program. We expected the first group of students to find the introductory courses for the first semester and to work logically out from there, choosing the courses that those introductory courses led to. We expected the second group of students to recognize where their list of already completed courses placed them within the flow of the program, and to be able to pick out which courses would come next. The second task was designed to test a student’s ability to recognize an overlap between curricula. We expected the subjects to choose the minor that would require the least amount of extra credit hours to complete. The third task tests a student’s ability to accurately backtrack through a sequence of course requisites.

3. **Results**
In general all participants in the CurricVis group enjoyed using the application and found it to be helpful in the decision-making process. Those in the control group who were
given a demonstration of CurricVis afterward agreed that it would have been much easier to complete the tasks they were asked to complete with the use of the application.

The tests identified a few minor problems with the software, but confirmed our assumptions that node-link diagrams are the most natural media for curriculum visualization; several participants in the control group even constructed their own node-link diagrams to help them feel out the “shape” of the academic program.

The minor problems the test revealed include:

- The lack of a color legend was a more significant issue than we had originally thought. Many subjects were confused about what the colored borders and text could mean. These colors were described on the “Welcome” page of the application, but we soon discovered that few users actually read that page thoroughly.
- The search bar used in the application did not function the way the users assumed it would.
- Some of the tabbed screens of the application began as blank screens until the user inputted data. Most users who saw these blank screens assumed the screens were broken and never revisited them.
- The application referred to the lines between the nodes as “edges” rather than the less technical “arrows.”
- There were some non-functioning aspects of the program that should have been removed before testing commenced.

Task Completion Success Rate

The first task, which asked the students to select the courses they would register for in the next three semesters, was graded on the feasibility of the subject’s plan. What is meant by a “feasible plan” is a plan that the student would actually be able to carry out. If the student attempted to sign up for classes that he or she had not satisfied the prerequisites for, then that would result in an unfeasible plan. Ten of the fifteen subjects in the experimental group (66%) and eight of the seventeen subjects in the control group (47%) were able to create feasible plans.

The third task, which asked the students to list the courses required to be eligible to register for CS457, was marked correct only for those students who successfully listed all of the prerequisites for that course. For the third task, 60% of the experimental subjects and 53% of the control subjects were able to list all of the requirements.
For the analysis of the data subject 28 has been assigned to the control group. That particular subject, while originally in the experimental group, never used the software we provided and completed the entire study under the same conditions as the control subjects.

Task two is not included because that particular question was more subjective than the others. In this version of the test we did not directly ask the subjects to choose a minor that would require the least amount of extra credit hours, or that would provide the most amount of overlap. We simply asked them to choose a minor and expected them to pick the minor that would require the least amount of work. That way we would be able to note whether or not the tool assists the students in coming to such a conclusion. Most students answered it by choosing a minor based more on their interest in that subject than on whether or not that minor overlapped with the Computer Science major chosen for them. Seven subjects in each category noted the overlap in their explanation of their
decision, but that does not necessarily mean that the other subjects did not notice the overlap. In future versions of this test, it would be better to directly ask the subjects to choose the “easiest” minor to take. Having the subjects come to the conclusion that they could use the program to find the easiest minor is not as important as knowing whether or not they can find the easiest minor.

**Task Ratings**

After the completion of the tasks, subjects rated the ease or difficulty of completing each task and their confidence in their answers on a 5-point Likert scale.

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<th>Difficulty 3</th>
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**Table 2: Questionnaire Likert Scale Results of the Experimental Group**

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Table 3: Questionnaire Likert Scale Results of the Control Group

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<td><strong>-0.25</strong></td>
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**Confidence**

Eighty-six percent of the participants in the experimental group marked that they were confident or very confident in their answers, with a mean rating of 1.14 on a scale from -2 (not confident) to 2 (confident). However, only sixty-three percent of the control subjects were confident in their answers, with a mean rating of 0.19 (p < 0.05). Students in the study who were using the curriculum visualization tool were significantly more likely to be confident in their answers.

**Question Difficulty**

It is clear from the difficulty ratings that subjects in the experimental group had an easier time completing the tasks than subjects in the control group. Only 21% of experimental subjects found the first task to be somewhat difficult (21%), with a mean rating of 0.57 on a scale ranging from -2 (difficult) to 2 (simple). In the control group, 75% of subjects described the first task as either somewhat difficult (50%) or difficult (25%) with a mean rating of -0.75 (p < 0.05). None of the experimental subjects considered the second task to be difficult, with a mean rating of 1.36. However, 43% of the control group marked it as either somewhat difficult (31%) or difficult (13%) with a mean rating of -0.25 (p < 0.001). The third task was relatively simple for both groups of subjects with a mean rating of 1.21 for the experimental group and 1.25 for the control group (difference not statistically significant).

**Time on Task**

The test administrators recorded the time on task for each participant. Each task was printed on a separate sheet of paper and the subjects were asked to turn over the page once they were finished with that task. The time on the stop watch was recorded at each page turn. The difference between the times of the two groups was not statistically significant.

**Participant Comments and Recommendations**

Upon completion of the tasks and questionnaire, participants were asked to write down any comments they had on the experience.
Comments on the text-based techniques
The following comments capture how the participants felt about the DAPR, the online course shopping cart, and the course catalog:

“I find the format of the DAPR to be extremely confusing.”

“DAPR is extremely unhelpful and not easy to use.”

These were common complaints from the participants in our study. At first sight, the DAPR is a massive wall of text that can be overwhelming, especially for students who want to make good curricular decisions that will lead them to a timely graduation.

Many of the subjects in our study felt that consulting the DAPR, the course catalog, and the online course shopping cart involved too much flipping between resources. Another subject expressed his complaint more thoroughly:

“Given all of the different choices of where to find the information was difficult because I didn’t know which one would be the most efficient. I found that different information was in different places (i.e. Requirements for courses are online not in the course book). Overall the process was hard to know if the outcome will be the way you want it.”

This comment is useful because it clearly demonstrates how confusing the text-based tools can be. This subject complains that the “Requirements for courses are … not in the course [catalog],” but they are listed in the catalog.

Comments on the curriculum visualization techniques
The following comments capture how the participants felt about the curriculum visualization software:

“It doesn’t say what the red words mean, all the arrows are hard to follow, it is very helpful in picking a minor.”

A few of our subjects had a hard time following what the different colors meant. There was a color key on the welcome screen of the application, but there should have been one on the screen that the users used most. This student enjoyed using CurricVis’ hypothetical mode to pick a minor that would overlap with her major. She marked all of the courses in the computer science major as hypothetically complete, and then browsed through the graphs of the minors she could choose from. She then picked the minor that had the most overlapped courses and the least left to complete.

“The system was pretty easy to use. I feel it would be easy to use the more familiar I was with it. I would like to see a little more interaction to view paths to courses as they were chosen.”
It would be interesting to see what difference a brief overview of the tools could make to the results of a revision to this study. The time it took for the experimental subjects to get acquainted with the software skewed their overall task times. This particular subject complained about not having enough "interaction to view paths to courses as they were chosen," but if he had been given a brief introduction to the software, he would have been able to use hypothetical mode, an aspect of the software that he did not discover during the test. When he saw hypothetical mode in use after his test, he said that it would have made everything "much easier."

**Recommendations from subjects**

Some of the subjects proposed useful additions to the software in their comments. Multiple subjects mentioned that it would be useful to have a view that displays a "recommended" four year plan for the chosen major. This feature could be implemented in the final version of CurricVis.

Another student suggested that we have a view that allows users to drag and drop courses into semester columns. CurricVis currently displays the courses in a node-link diagram where the nodes are interactive but immovable. Allowing the students to move the nodes around as they wish would allow them to view the information in a way that could be more comfortable to that user.

4. **Discussion**

The results of this study indicate that curriculum visualization techniques can be used to greatly assist students in making curricular decisions. Students who used CurricVis in the study were significantly more likely to be confident and accurate with their answers than students who used traditional, text-based methods. CurricVis also eased the strain of making curricular decisions, resulting in a significantly lowered perceived difficulty rating from students in the experimental group. This higher confidence, higher accuracy, and lower perceived difficulty can be attributed to the power of feedback. The text-based modes for curricular communication have no method for providing feedback to the user, unless that user consults with an advisor. The students who used the course catalog and the DAPR could read both documents thoroughly and would still not feel as confident as they would with a simple feedback mechanism. CurricVis provides that feedback mechanism with visual cues; a course that a student cannot register for, for whatever reason, appears in a different color than a course they have already taken or a course that is available to them. Whether or not a course node is interactive is also a feedback mechanism, which has a direct impact on the higher accuracy. Students basing their answers solely off of the information they gathered from CurricVis simply were not able to make incorrect decisions.

The time for each task was surprisingly similar between the two groups. Even though the experimental group was more likely to have higher confidence in their answers and more
likely to find the tasks to be easier, they still took about the same amount of time on each task as the participants in the control group. One possible explanation for this could be the unfamiliarity of the subjects with CurricVis. Many of the experimental subjects spent a few minutes skimming the “Welcome” page on CurricVis, which gave them a brief overview of how to use the software. Some subjects also took a few minutes getting a feel for the software by clicking through its tabbed windows and the navigation tree. Participants in the control group, on the other hand, were all experienced with the tools they were provided, and were able to jump right into the tasks. An interesting future adaptation of this test could involve giving both groups of participants a short tutorial of how to use the tools before giving them the tasks to complete.

Most of the participants found CurricVis to be a useful and easy to use tool for making curricular decisions. Many subjects were very interested in having an application that could provide them with all of the information they needed in one location, rather than the current system which requires flipping through multiple locations both online and in course catalogs. Students who use curriculum visualization tools are more confident in their answers and are able to make common curricular decisions with lower perceived difficulty than students relying solely on text-based methods.

5. Future Work
CurricVis has so far been developed to fulfill the needs of the usability testing and analysis and, therefore, is still in a prototype stage. An integration of CurricVis with university data and services is the next logical step of development, leading to a wider deployment and eliminating the need for hand coding the curricular data. In terms of research, the next step will be to test the efficacy of curriculum visualization techniques among academic advisors, curriculum designers, and administrators.

It would also be interesting to compare curriculum visualization techniques with text-based techniques among international students or students who speak English as a second language. Even international students who speak English pretty well can have a difficult time with the technical language in the course catalog and the DAPR, but an interactive curriculum visualization system like CurricVis could give them the ability to schedule their own courses without the constant supervision of an advisor.

There is still work that can be done from the results of this study as well. A more in-depth analysis could be made by comparing the times, accuracies, and confidence levels between experimental users who used the welcome page, hypothetical mode, and/or the progress view and those who did not. It is possible that the students who read through the welcome page and discovered hypothetical mode were more confident in their answers and found the questions to be easier. There were also many “guessers” who participated in our study, particularly when it came to the second task of choosing a minor. It would
be interesting to see the affect on the results of removing the times of those students who were simply guessing.

Works Cited

IRB Documentation

Subject Questionnaire
Each subject completed this questionnaire after completing the task sheet.

Answer the following questions on a scale from -2 to 2.

-2 – not confident, difficult
-1 – somewhat not confident, somewhat difficult
0 – neutral
1 – confident, somewhat simple
2 – very confident, simple

1) Overall, how confident are you with the answers you have provided?

   -2  -1  0  1  2

2) How difficult did you find each task?
   a) Task 1 (choosing classes for the first three semesters)

      -2  -1  0  1  2

   b) Task 2 (choosing a minor)

      -2  -1  0  1  2

   c) Task 3 (listing the sequence of courses required to take CS457)

      -2  -1  0  1  2
Proctor Script
This is the script the proctor of the study read to each subject prior to administering the task sheets.

Thank you for participating in our study. Please read the informed consent form completely and sign. Your participation in this study is voluntary, and at any time during the study you can leave without penalty. Your responses are completely anonymous and your name will not be connected in any way with your responses. For your participation in this study, your email address will be entered into a drawing for one of two pre-paid gift cards.

You will be given three task sheets. Please complete the tasks in order. After you complete each task, turn the page over to indicate to us that you have finished the task. There are no right or wrong answers to these tasks, we are more interested in your decisions and your decision making process. If you have any questions about this study, you may contact the Principle Investigator, Austin Toombs, at altoombs@bsu.edu. It is estimated that this will take twenty-five to forty-five minutes. Thank you for your time. You may begin now.
Study Description
This is the study description that was handed to each student.

Study Title
The impact of curriculum visualization on decision making among students.

Study Purpose and Rationale
The purpose of the study is to measure the effects a curriculum visualization tool has on students' abilities to make decisions. We will be comparing these findings with the effects of using only traditional, text-based curricular data. Working with course catalogs, the DAPR system, the course shopping cart, and the course request system is confusing for most students. With these resources it is difficult for students to make good decisions about which courses to enroll in, the order in which to take a sequence of courses, which minor to choose, and which major or option to switch to. CurricVis is a system that utilizes curriculum visualizations to help students build more accurate mental models of curricular programs. This study will determine whether or not CurricVis functions as a positive aid to the decision making process among students. No other research on curriculum visualization has included such a study on usability.

Inclusion/Exclusion Criteria
To be eligible to participate in this study, you must be at least 18 years of age and have never been a Computer Science major.

Participation Procedures and Duration
For this project, you will be asked to complete a series of curriculum-related tasks and a questionnaire about those tasks. It will take between 20 and 45 minutes to complete the tasks and the questionnaire.

Audio or Video Tapes
There will be no audio or video recordings used in this study.

Data Confidentiality or Anonymity
All data will be maintained as confidential and no identifying information such as names will appear in any publication or presentation of the data. All data in this study is anonymous.

Storage of Data
Paper data will be stored in the PIs office while the data is analyzed (maximum of three years). After which the paper documents will be shredded. Only members of the research team will have access to the data.

Risks or Discomforts
There are no risks or discomforts associated with this study.

Who to Contact Should You Experience Any Negative Effects from Participating in this Study
Should you experience any feelings of anxiety, there are counseling services available to you through Lucina Hall room 320 at Ball State University in Muncie, 765-285-1736.

Benefits
This study has potential benefits to you, the investigators, and to Ball State University. By participating in this study, you are helping the investigators fulfill a vital stage in the development of a software application. If it proves to have a positive impact on decision making abilities of students, then the software will be made available to the students through the university. It will then be used by students, advisors, and curriculum designers to relieve the stress of understanding curricular data.

Voluntary Participation
Your participation in this study is completely voluntary and you are free to withdraw your permission at anytime for any reason without penalty or prejudice from the investigator. Please feel free to ask any questions of the investigator before signing this form and at any time during the study.

IRB Contact Information
For one's rights as a research subject, you may contact the following: Research Compliance, Sponsored Programs Office, Ball State University, Muncie, IN 47306, (765) 285-5070, irb@bsu.edu.

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IRB Certification
Similar certificates were acquired for both Jordan Turpen and Gunnar Hoffman, who co-proctored the study.
Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that Austin Toombs successfully completed the NIH Web-based training course "Protecting Human Research Participants".

Date of completion: 09/14/2009

Certification Number: 292847