1-1-2014

Exploratory study of student instructional choice in online learning

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Exploratory Study of Student Instructional Choice in Online Learning

by

Andrew J. Hurd

A Dissertation
Submitted to the University at Albany, State University of New York

Submitted in partial fulfillment of the requirements for award of the degree of
Doctor of Philosophy in Information Science

Informatics Department
University at Albany
State University of New York

by

Andrew J. Hurd
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Acknowledgments

There are many people I would like to acknowledge for their support but the first person is my wife Jennifer: without your support I would have not completed this dissertation. In June of 2004 when I said I wanted to get my doctorate, you told me I was crazy and I had no idea the amount of work it was going to take. You were correct, but your support was priceless. The countless hours that you handled everything I haven’t had time to handle can never be quantified. I love you and always will.

To Alexander and Abigale, my wonderful children. You share in this accomplishment as much as anyone. I have sacrificed many hours of being with you and not attending events that you were part of to complete this process. I will try my best to never say, “I can’t be there because I have to go to the library!” A driving factor in this process was your never-ending question, “Is it done yet?” I can now answer, “YES!” Always have confidence in your abilities and complete what you start, even if the path is difficult.

To my parents, Charles and Gloria Hurd and my family, Chuck and Liz, Tim and Kathy, Nancy and Tom, Matt, Jeanine, Kenny and Brandi, Jen and Greg and all of my nieces and nephews, thank you for all of the support and the excitement along the way. Every time I told you of my accomplishments you showed me more support than anyone could ever hope for.

To my grandmother Jennie Revette, I only wish I had completed this before you left our world. I know you would have asked me to explain this document to you and you would have smiled, shook your head, and said, “I still don’t understand”, but you would have listened to every word with a smile on your beautiful face.

To Philip and Constance Newell, thank you for all the support and help with the house and kids.
The countless times that you were there to help when I couldn’t be can never be repaid. I know you don’t need repayment, you did it out of love and that means the world to me.

To the rest of my friends and family, who are too numerous to mention by name, thank you for all the support, it was a huge factor in this process.

To my committee, Dr. Joette Stefl-Mabry, words cannot express the respect and admiration I have for you. Thank you for believing in me and having faith in my abilities to complete this process. Your guidance has been invaluable. To Dr. William Doane, I want to say “I did it!”, but you would correct me and tell me that “I completed it”. Without your guidance and your support I would have never completed this dissertation. You have made me a better writer, a better researcher, and a better educator. The conversations we had during this process will be the fondest memories I will have of it. To Dr. George Berg, thank you for being the strong silent one; the voice of reason and the voice of good questions.

To Ira Goldstein, Fawzi Mulki, Steve Lackey, and many other Ph.D. students, thank you for all the conversations we had and making the doctoral program enjoyable.

To Dr. Deborah Andersen, thank you for believing in me and championing my second chance. I hope you continue to pass your knowledge on to students and encourage them to always be their best.

To Dr. James Looby, thank you for working with me and being a voice of reason when the way wasn’t always clear. As my department chair the support you have shown me has been instrumental to my success.

To Robert Matthews, thank you for the help with the literature review. I greatly appreciated all of your help.
To the professors who allowed me to use their classrooms for research, thank you for the opportunity to do research in your classroom. Your generosity was greatly appreciated.

To anyone who reads this dissertation, thank you for taking the time to read what I wrote; hopefully it will help. Remember: as educators we have a responsibility to share knowledge and I hope you enjoy what this study has to say.
Abstract

This exploratory study considers choice theory, decision theory, and the constructivist theory of education to explore college-level computer science learners’ behavior when presented with multiple instructional modes (instructional methods for the presentation of course content, such as video, text, audio, animation, etc.) in an online learning environment.

Demographic, performance, and behavior data were analyzed using exploratory data analysis techniques—including recursive partitioning, linear modeling, analysis of variance, and elemental graphics visualizations—to determine which factors serve as the best predictors of learner behavior, i.e., which factors best predict learners’ choices of instructional modes.

Learners enrolled in introduction to computer science courses at 4 two- or four-year colleges in the Northeastern United States completed 3 online learning modules. Each module included 5 different instructional modes learners could choose to access. Participant behaviors while completing the modules were recorded using learning management system (LMS) logs.

The study found that participants did not avail themselves of the multiple instructional modes presented in the online modules. Demographic variables such as age, gender, number of semesters in college, and previous online course experience were not found to be consistent, statistically significant predictors of participants’ behavior.
Chapter 1. Introduction

What if the individual learner were given the opportunity to choose the way in which he or she were going to receive instruction? What if an online course provided a variety of instructional modes: video, lecture, notes, animation, and simulation? How would this shift of focus—away from teacher-centered instructional design toward learner-centered instructional choice—change the educational experience for the learner? Will learners demonstrate an increase in the degree of attainment of intended learning outcomes if provided with the choice of instructional mode?

In existing online learning environments, content is either fragmented—e.g., accessing Khan Academy via YouTube’s user interface—or modeled on existing university structures: courses, class instances taught by one (or a small number of) teacher(s), terms (quarter or semester), and lectures supported by readings and discussion boards. The educator chooses the instructional delivery methods, possibly with the assistance of instructional designers.

One possibility for changing the educational experience seems as yet unexplored: allowing the learner to choose their own instructional delivery method; a choice that has been rare for learners, since most formal learning settings offer one educator teaching a given course in a given mode at any point in time. Now, with many different teachers’ approaches to instructional modes available online, there exists the possibility of allowing learners to choose who their teacher will be and what modes of instruction they will use on a topic-by-topic basis. Bransford et al. (1999) explained

New developments in the science of learning also emphasize the importance of helping people take control of their own learning. Since understanding is viewed as important, people must learn to recognize when they understand and when they need more
Empowering the learner— with choices of the instructional mode within each learning module— will allow him or her to take control of his or her preferred instructional method.

Young (2011) found that 18.2% of people who used the Google search engine selected the first item on the list and 10.05% selected the second item. A possible reason for these numbers may be people either feel comfortable with the suggestions Google provides and/or they are too impatient to read through all of the search results to find the desired resource. If the educator took the time to find these resources or if their colleagues created these resources then the learning experience may increase the attainment of learning outcomes.

For example, learners might be presented with a course in which topics are sequenced according to a given educator’s view of an appropriate path through the learning material. This provides a structure within which the learner could be presented options: for each topic, several alternative methods of presenting that topic— perhaps prepared by different teachers, possibly at different institutions— could be offered to the learner, who is then free to choose as many of the presentations as they want or need in order to educate themselves on the material.

Bakarman (2005) defined education as the attitudes, skills, and knowledge gained based on the assessment of the student learning outcomes. In a learner-centered environment, learners’ attitude, opportunities, and choices determine the education they will receive. It is not up to the learner to decide what they will learn but it is up to them to decide how they will learn.

How would learners react to the availability of a learner-centered environment that provided them with the ability to educate themselves?
Would learners opt for the minimal path—always choosing the same method of content delivery—or would they consider several modes for each topic?

Would learners always select the same instructor’s presentations as they proceed across topics, or would they feel free or comfortable to sample from multiple instructors’ approaches to teaching?

Would the availability of additional modes of instruction affect the degree of attainment of intended learning outcomes?

**Significance of this study**

Computer Science (CS) enrollment is on the rise, the dropout rate of online classes is large ("College online courses are costly, result in high dropout rate, report says.", 2013), the dropout rate of colleges is high especially in Science, Technology, Engineering, and Math (STEM) (Tabarrok, 2012, March 4), and there is always a need for improved pedagogical styles for teaching computer science (Schacter & Fagnano, 1999).

The Computing Research Association (CRA) reports that

The number of new undergraduate computing majors among U.S. computer science departments rose an astonishing 29.2 percent, 22.8 percent among those departments reporting both this year and last year. This is the fifth straight year of increased enrollment in computing majors by new students (Zweben, 2011 p. 2).

The increase in majors creates a larger population for research. If the enrollment in CS or related degrees is on the rise, then more students will be enrolled in introduction to CS or related classes.

As of 2012, there are approximately 56,000 students majoring in computer science in the U.S. (see Table 1). There are about 17,000 new BS CS majors. The large numbers reported is not a true representative of CS majors. It includes computer engineering (CE) and information (I)
majors. In 2012 13,055 Bachelor of Science CS-related degrees were awarded in the US, but only 9,867 were CS majors (see Table 2).

**Table 1. Computer science enrollment**

<table>
<thead>
<tr>
<th></th>
<th>2011-2012</th>
<th></th>
<th>2012-2013</th>
<th></th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Headcount</td>
<td>Mean Enroll</td>
<td>Headcount</td>
<td>Mean Enroll</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>6,576</td>
<td>60.9</td>
<td>7,297</td>
<td>67.6</td>
<td>11.0%</td>
</tr>
<tr>
<td>Public</td>
<td>4,797</td>
<td>137.1</td>
<td>5,329</td>
<td>152.3</td>
<td>11.1%</td>
</tr>
<tr>
<td>Private</td>
<td>1,779</td>
<td>24.4</td>
<td>1,968</td>
<td>27.0</td>
<td>10.6%</td>
</tr>
<tr>
<td>Master’s granting</td>
<td>3,680</td>
<td>136.3</td>
<td>4,197</td>
<td>154.4</td>
<td>14.0%</td>
</tr>
<tr>
<td>Non-master’s granting</td>
<td>2,359</td>
<td>31.5</td>
<td>2,525</td>
<td>33.7</td>
<td>7.0%</td>
</tr>
<tr>
<td>CS Tauhbee</td>
<td>48,817</td>
<td>367.0</td>
<td>56,742</td>
<td>599.6</td>
<td>8.9%</td>
</tr>
</tbody>
</table>

(CRA Computing Degree and Enrollment Trends 2013)

**Table 2. Computer science degrees awarded**

<table>
<thead>
<tr>
<th>Department Type</th>
<th># Depts</th>
<th>CS</th>
<th>CE</th>
<th>I</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>US CS Public</td>
<td>105</td>
<td>7,615</td>
<td>1,578</td>
<td>1,004</td>
<td>10,291</td>
</tr>
<tr>
<td>US CS Private</td>
<td>37</td>
<td>2,248</td>
<td>268</td>
<td>338</td>
<td>2,854</td>
</tr>
<tr>
<td>Total US CS</td>
<td>142</td>
<td>9,867</td>
<td>1,846</td>
<td>1,342</td>
<td>13,055</td>
</tr>
<tr>
<td>US CE</td>
<td>9</td>
<td>0</td>
<td>406</td>
<td>0</td>
<td>406</td>
</tr>
<tr>
<td>US Info</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>1,190</td>
<td>1,190</td>
</tr>
<tr>
<td>Canadian</td>
<td>14</td>
<td>1,182</td>
<td>104</td>
<td>38</td>
<td>1,324</td>
</tr>
<tr>
<td>Grand Total</td>
<td>174</td>
<td>11,049</td>
<td>2,356</td>
<td>2,570</td>
<td>15,975</td>
</tr>
</tbody>
</table>

The average number of CS majors in a degree is also on the rise (see Figure 1). This means that there are more students with possible different instructional preferences. It becomes apparent that educators may need to adjust their instructional practices to meet the increase in different instructional preferences.
Figure 1. Average number of CS majors

![Graph showing average number of CS majors from 1999 to 2011]

*CRA Computing Degree and Enrollment Trends 2012

The mean number of learners majored in CS is approximately 412 per department. The number of female CS majors rose slightly in 2012 up 1.2% from 10.6% to 11.8%. These numbers also represent the female learners in computer engineering or information majors.

**Purpose**

The purpose of this study was to explore the choices learners make when presented with different instructional modes in an online module. Robert Glaser’s instructional model for learning object assessment includes an *Instructional Procedure* aspect that is relevant to this study. Glaser’s model describes the methods by which an educator can create his or her material to address the way students learn (Glaser, 1962; see Figure 2 in *Chapter 2. Related Literature*). This study reflects the *Instructional Procedure* area of the model in that only the particular presentation of instructional materials to the learner is in question.
Approach

The learner was presented with three different learning modules related to computer science topics: binary numbers, If statements, and boolean algebra. The topics for each module were selected from the IEEE curriculum standards. These topics were also cross-referenced with Computing Curricula 2005: The overview report (Shackelford et al., 2006). If the introduction to computer science class does not include the topics then other introductory classes the learner should be taking in their first year will cover the topic. These topics underlie many other computer science topics.

For each module, learners were provided with five instructional modes, such as video, text, animation, and/or any other instructionally appropriate materials available on the web. The five modes came from a variety of popular online resources including video hosting services, providers of online courses, and lecture notes. This differs from Glaser’s model where the educator provides a single mode of instruction to the learner.

If it is found that availability of choices within a learning module improves learner attainment of intended learning outcomes in an online environment, then this information may be used in the course design of online modules or Massive Online Open Collaborations (MOOCs).

Research questions

The study focused on the number of instructional modes selected by students when multiple modes are made available. Therefore, the research questions addressed by this study involve the characteristics of participant selections and the relationship of the number of instructional modes selected to other predictor variables.
1. What is the mean number of instructional modes selected per module?

2. Do pretest scores correlate with the number of instructional modes selected by participants?

3. Does the number of instructional modes selected correlate with an increase in posttest scores?

4. Is gender correlated with the number of instructional modes selected?

5. Is age correlated with the number of instructional modes selected?

6. Is previous online class experience correlated with the number of instructional modes selected?

7. Does institution type correlate with the number of instructional modes selected?

8. Does the number of college semesters completed correlate with the number of instructional modes selected?
Chapter 2. Related Literature

Online Learning

In online learning course content is delivered via the World Wide Web ("the web"). An online learning experience can either be synchronous or asynchronous.

*Synchronous online classes* are those that require learners and instructors to be online at the same time. Lectures, discussions, and presentations occur at a specific hour. All students must be online at that specific hour in order to participate.

*Asynchronous classes* are the opposite: Instructors provide materials, lectures, tests, and assignments that can be accessed at any time. Learners may be given a timeframe – usually a one week window – during which they need to connect at least once or twice. But overall, learners are free to contribute whenever they choose.

(Synchronous vs. Asynchronous Classes, paragraph 1 & 2)

*Distance teaching* is defined as

The family of instructional methods in which the teaching behaviors are executed apart from the learning behaviors, including those that in a contiguous situation would be performed in the learner’s presence, so that communication between the teacher and the learner must be facilitated by print, electronics, mechanical or other devices (Moore, 1973, p. 664).

These definitions suggest an approach that is difficult to manage as well as to implement: if a teacher wishes to provide their online course in a *synchronous* manner then they must allocate time and resources to be available for learners (Jonassen & Driscoll, 2013). This is daunting and does not enable educators to scale learning experiences to large numbers of learners. If a teacher decides to offer their course in an *asynchronous* course design then the learners are left to decide when and how much time to allocate to complete the tasks. This is subject to procrastination and hurried work when the deadline approaches. Miller (1997) found that these two approaches have similar outcomes and grades when applied to classroom instruction. Miller
determined that the manner in which the class was presented —synchronous or asynchronous— did not affect the grades of the class. Miller explained that motivation was the largest factor to get students to complete the work. Wojciechowski & Palmer (2005) found that previous online classroom experience is a statistically significant predictor for success in online classes.

In each approach, the focus is on one teacher delivering content to many learners. Which approach is the best? There’s likely to be no single answer. Still, the structure of the course is a necessary concern.

Kearsley and Lynch (1996) believed that the structure of an online class was depicted in the syllabus of the class and set forth in the learning environment. They described the most important structure of the course as the syllabus. The syllabus typically gives structure to the learning objectives and defines the schedule of instruction.

Should an educator assume that the learner would have the motivation to read or practice the material in a given module? This is the basic premise of an online educational class, but in online asynchronous classrooms learners are allowed to approach the module in any way they wish. This can be controlled by adaptive releases of material, when material opens once certain content is completed. This type of control is easier in a synchronous class where the educator can require all learners to be in the same area of the module. Researchers have tried to discover which form of online educational class is better, but the results have been inconclusive (Gunawardena & McIsaac, 2004; Hrastinski, 2008).

Theoretical Framework

When learners do not complete assignments we, as educators, speculate that the learner can’t
do the work. This may not be the case: they might not be *learning* the way we are *teaching*. This is not to say that we need to cater to the instructional preference of every learner. This would be an impossible task for the educator. The educator should access the lesson plan that they have created or one that has been provided to them. After consulting the lesson plan the educator is responsible for teaching material to the learner in whatever way the educator chooses, this means that the educator is responsible for providing the information in a way that will get the material across to their class. Sometimes the educator is told what methods to use to convey the information, but other times it is up to the educators’ creativity to teach the material that meets the learning objectives.

The educator decides what material will be graded and what material is not graded and could be presented for knowledge gain. The learner’s role is to use the provided material as well as any resource they may find to complete the assignments for that module. If the learner doesn’t like, or is having difficulty learning the material in the manner the way the instructor is presenting it what are they left to do? They could ask for help but learners may feel threatened or embarrassed by asking questions. Learners may not realize that this is what the classroom is for, to facilitate their instructional preference, and to provide them with instructional support. It is well documented that most learners will not ask for help when they need it (Ryan et al., 1998).

Educators may not be prepared to teach the material; this is especially true when it comes to technology topics. Researchers have identified that technology educators may be under-prepared to teach the material because the subject matter may be too new (Khumalo, 2004). Using the web to locate appropriate resources can compensate the lack of knowledge and/or skills. The educator can find resources on the web that explain or teach the material they lack the skill to properly teach. New opportunities are offered to educators with the availability of
the web, educators share their content and their material provides other educators with an abundance of resources. The learner can remix and re-present many educators’ approaches to a topic, allowing the learner to make the choice of which instructional modes suits his or her preferred instruction.

Content and material is not enough for an educator. The material needs to be organized into lessons that have clear learning objectives. Morris Keaton (2004) stated that

The principle that an instructor should make clear the learning goals and objectives of a learning experience (course, workshop, training event) and make one or more paths to their achievement clear to students and keep them clear. Among the ways to do so is to state these goals and paths in a syllabus (p. 2).

Keaton emphasizes that educators should focus on getting the material across to learners in multiple ways. They should focus on the manner in which the majority of their learners will grasp the material. This pedagogical style is subject to change if a different methodology is introduced that meets the learners’ needs.

**Choice Theory**

In Choice Theory (CT), Glasser describes ten axioms (see Table 3) that underlie the need for choice. Not all of the axioms are applicable to education but when a couple of them are applied they depict a strong picture for a new approach.
Table 3. Glasser’s axioms of Choice Theory (CT)

<table>
<thead>
<tr>
<th>Axiom number</th>
<th>Axiom</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The only person whose behavior we can control is our own.</td>
</tr>
<tr>
<td>2</td>
<td>All we can give another person is information.</td>
</tr>
<tr>
<td>3</td>
<td>All long-lasting psychological problems are relationship problems.</td>
</tr>
<tr>
<td>4</td>
<td>The problem relationship is always part of our present life.</td>
</tr>
<tr>
<td>5</td>
<td>What happened in the past has everything to do with what we are today, but we can only satisfy our basic needs right now and plan to continue satisfying them in the future.</td>
</tr>
<tr>
<td>6</td>
<td>We can only satisfy our needs by satisfying the pictures in our Quality World.</td>
</tr>
<tr>
<td>7</td>
<td>All we do is behave.</td>
</tr>
<tr>
<td>8</td>
<td>All behavior is Total Behavior and is made up of four components: acting, thinking, feeling and physiology</td>
</tr>
<tr>
<td>9</td>
<td>All Total Behavior is chosen, but we only have direct control over the acting and thinking components. We can only control our feeling and physiology indirectly through how we choose to act and think.</td>
</tr>
<tr>
<td>10</td>
<td>All Total Behavior is designated by verbs and named by the part that is the most recognizable.</td>
</tr>
</tbody>
</table>

Axioms 2 and 9 describe the learner-educator interaction in its modern sense. The learners’ behavior is chosen and all the educator will provide is information.

**Decision Theory**

*Decision theory (DT)* is the process of making decision based on what problem or situation is at hand (Berger, 1985). In 1954 Ward Edwards stated that “...the theories of decision making are static theories. They are concerned with determiners of a single choice among courses of actions, rather than with a sequence of choices” (Edwards, 1961, p. 474). Online learning
modules are created as a series of problem solving tasks that are based on the learners’ choice. When the learner enrolls in a course the material will be presented either asynchronously or synchronously. The educator decides to develop their class or modules in a path or a series of tasks that the learner completes to attain enough information to complete the learning objectives for that module. Using Edwards’ theory that decisions are static theories and that learner’s choice is only a single choice among a course of action, a learner is left to follow the direction of the educator in whatever manner the material is presented. If the material is presented in a numerical list from 1 to N, then the theory states that the learner should complete the steps in a sequential process.

When an educator develops an online course they should be working closely with instructional designers to use the best practices in preparation of their courses. Well-structured problem solving approaches are rooted in information-processing theory (Jonassen, 2000). Jonassen feels that “ill-structured problems share assumptions with constructivism and situated cognition” (p. 64). Therefore the manner, in which the educator develops and presents the material, will directly influence how the learner will approach the problem.

Duffy and Jonassen (1992a) also believe that educators tend to develop courses a little differently than the instructional designers suggest. The educators want to “lead” the learner to a specific learning outcome. The instruction that leads the learner through modules commonly has a path they wish the learner to follow. Educators use this philosophy when designing their course modules and this is communicated through the schedule that can be found in the syllabus. The syllabus should be the first form of communication with the student (Kearsley & Lynch, 1996). It should be clear what the expectations are for each module, but it should be left
up to the structure of the module as to which part the learner does first. If all components of the module open and closed at the same time then the learner can choose what part of the module they are going to attempt. There may be a logical path that would lead to the learners’ best performance, but it is up to the learner to follow it. The learner may not want to read the chapter before they attempt the quiz. This may not be advised if the quiz can only be taken once per module, but if the quiz can be taken more than once then the learner may want to test their knowledge before they begin. If the quiz is the only assessment within the module then if the learner takes the quiz with the impression that they can take it more than once, then they do what they feel is well enough the first time the learner may skip all of the other work within the module. They may feel that they already know the material well enough.

If the module is created to reflect the instructional design of Duffy and Jonassen then the educator provides a list of tasks that are tied to specific learning outcomes. The learner should attempt them in any order or manner that suits their learning style. The educator has the design freedom to bring in outside resources to their classrooms. If the educator does not bring in outside resources the learner are free to search the World Wide Web for resources to help them understand the subject matter. While learners move away from the online class, they could become distracted from the course content; it is up to the learner to stay on task. The learner has the responsibility to complete the assigned work.

What if the module were a conglomerate of material from the World Wide Web? What if the learner had a variety of modes within a module from the Internet? What if the learner could choose any or all of these modes to help them attain the learning objectives? How many resources would the learner choose, if they did poorly on a pretest? Would the learner still choose to go outside of the class to try and find a resource that might provide the answer to a
question about the learning objective or is the learner willing to work through the material within the module to acquire the knowledge?

Sniderman and Bullock (2004) studied the effects of consistency of a menu of candidates within a political website interface. The consistency of a menu has a direct effect on what choices the user will make. It is not solely consistency but it is also organization of this menu. Sniderman and Bullock assume that people will be motivated and consistent in their menu choices when dealing with interfaces that have a political connotation. When dealing with politics this can be expected, but does this transfer to education? Studies demonstrate there may be selection bias based on positioning of items within menus (Rouet et al., 2011; Cockburn et al., 2012). To eliminate selection bias the menu can be manipulated and presented in different sequences.

**Constructivist Education Theory**

Constructivist theory is a foundation in education that describes building blocks for a learner. The core building block is that knowledge is constructed through any information a learner comes into contact with. The information gained from this contact adds to their existing knowledge and experience. The constructivist approach to problem solving describes that the learner builds their own knowledge facilitated by the resources around them (Cunningham & Duffy, 1996). Glasersfeld (1989) felt that the responsibility of learning fell to the learner to gain these experiences and that objective knowledge cannot be expressed in words. Objective knowledge refers to “...the bucket theory of the mind. The mind is an empty bucket in which knowledge is poured” (Popper, 1972, p. 2). This means that if any learning occurs where *information* is taught or knowledge is *conveyed* based on experience; then it will reside within the constructivist theory of education.
Educators are responsible for the presentation of material in such a way that the learners need to be able to foster ideas or build on their own knowledge. Carter (2009) explains that a course module that provides a series of tasks and then presents an activity to assess the learning outcomes did not support the theory of constructivism. There would be no place to foster ideas or construct knowledge. The information gain would only be what the educator provided. The idea that learners would be left to explore and learn information on their own goes against the traditional model of a classroom. What would the educator do if they were not there to provide the information to the learner? If learners were not given direction in the traditional sense of a classroom then the learner would “float” around and wouldn’t grasp what was going on (Maia et al., 2005). This does not take into consideration students learning on their own. Classrooms, either traditional or online, should be dynamic and engaging. It should be made up of learners who collaborate in the process of teaching and learning (Gray, 1997). The learners should strive not to present only the simplest of answers but to cultivate the knowledge from many areas and synthesize a response to a question or learning objective. The learner must have the freedom to incorporate their own ideas based on their previous knowledge if this is the desired outcome.

Unfortunately most learners are not encouraged to think on their own; they are encouraged to find the right answer. This is understandable, but not realistic for methods that are holding back learners and educators.

Constructivist methods have been successful in exploratory learning as well as problem-based learning (Makgato, 2012). The desired outcome of an exploratory or problem based learning module is that the learners’ will obtain, either through activity or constructivist behaviors, enough information to attain the learning objectives. If the learner does not attain sufficient knowledge, then they may not do well on the assessment of the learning objectives. With constructivism, learners must be given the opportunity to engage and foster ideas with each
other as well as the educator. This can be achieved through proper instructional design and module creation (Gueldenzopf, 2003). The course can be designed so that learners are given opportunities “which compel them to read, speak, listen, think deeply, and write” (Dodge, 1996, p. 1). Learners must be motivated for constructivism to emerge in their learning process. Grier-Reed and Conkel-Ziebell (2009) propose that learners need to be able to generate their own skill set because modern careers are “forged rather than foretold” (p. 2). Learner interaction and derivation of their own skills become essential to forge their own career and is essential for them to succeed in the classroom.

**Glaser’s Instructional Model for Education**

Glaser’s (1976) instructional model details four areas for proper attainment of instructional material (see Figure 2). This model was designed to explain the difference between instruction and teaching. Glaser spent a great deal of time exploring the proper way to write learning objectives and having his instructional material centered on learning objectives. Glaser felt that proper instructional design of material would lead to better attainment of material for learners.

**Figure 2. Glaser’s instructional model**

Glaser’s model defined four areas:

**Instructional Objectives**

Area of the model where the learning objectives are explained to the learner.

**Entering Behavior**
Area of the model where pretest or any other pre-data needs to be collected.

**Instructional Procedure**

Area of the model where the educator provides their content material to the learner.

**Performance Assessment**

Area of the model where the educator administers any assessment of learning objectives for the module.

This model was designed for a 1:1 learner-educator model where the educator develops material and presents it to the learner. The educator has to decide on the preferred mode of instruction. Hersh and Cohen (1972) demonstrated that educators choose modes that may not fit their learners’ learning needs.

Hersh and Cohen used Glaser’s model and explained the importance of writing proper learning objectives that reflect Bloom’s Cognitive Taxonomy. They explained that in Glaser’s model the **Instructional Procedure** area is where the educator is responsible for presenting the material to the student. Hersh and Cohen explain that

> Any teaching strategy a teacher chooses can be seen as an attempt to individualize learning, since each individual is expected to benefit from such activities. But each individual may not benefit. Teachers do not always choose teaching strategies appropriate to the learning objectives. Teachers sometimes choose inappropriate strategies because their objectives are so vague as to be meaningless (p. 104)

Hersh and Cohen also talk about Individualizing education for the learner and how it matters if the learning objectives are clearly defined and if the **Instructional Procedures** are centered toward the learning objectives.

Using Glaser’s model, Snyder (1975) came to the conclusion that
Before this instructional model can be employed, much preliminary work must be done. Clearly stated objectives must be written; diagnostic tests must be formulated; instructional procedures that help the individual learner must be developed; and performance evaluations must be prepared. The work involved is more than one instructor should be expected to handle (paragraph 12).

Snyder believed that this was too much work for one educator to handle and for proper educational measures the work should be distributed as to facilitate an opportunity for the learners’ attainment of the material.

**Apparent Gap in Literature**

Review of the literature reveals a lack of application of *choice theory, decision theory* and the constructivist theory of education to online learning design. *Choice theory* is extensively applied to areas of political sciences; *decision theory* has foundations in mathematics and statistics. However, they have not been applied to online learning or learner choice of instructional modes. Learner choice is applied to which classes the learner will take and whether the learner wants a face-to-face or online class, but the reviewed literature does not address the integration of learners’ choice of their instructional mode.

Lee Shulman (1986) expounded upon the constructivist theory of education and developed the *Pedagogical Content Knowledge* (PCK) approach to learning. This theory explains that educators need to have a form of certification or verification of their own education. One of the fundamental principles of constructivist theory is:

> Teaching should enable students to fill the gaps and extrapolate information and materials presented by the teacher. The goal should be to empower learners with skills to be independent, and access use [sic] relevant information from various sources to answer their problems and challenges (Makgato, 2012, p.1399).

This principle is also present in PCK. This explains learners should be empowered to be
independent and free to make positive choices. Searching scholarly journals it is apparent that CT and DT when applied to online or distance learning scenarios, is an area that needs further exploration.

**Table 4. Sources for literature review**

<table>
<thead>
<tr>
<th>Databases</th>
<th>Primary Search Terms</th>
<th>Secondary Search Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Academic Search Complete</td>
<td>● Choice Theory</td>
<td>● Online learning</td>
</tr>
<tr>
<td>● ACM Digital Library</td>
<td>● Decision Theory</td>
<td>● Distance learning</td>
</tr>
<tr>
<td>● Education Source</td>
<td>● Constructivism</td>
<td></td>
</tr>
<tr>
<td>● Computer Source</td>
<td>● Constructivist</td>
<td></td>
</tr>
<tr>
<td>● ERIC</td>
<td>● Student choice</td>
<td></td>
</tr>
<tr>
<td>● ScienceDirect</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Using a series of databases and search terms (see Table 4) as of this date there appears to be little evidence of documented research of the integration of CT or DT as it pertains to computer science education (see Appendix A).

Papers within the databases discuss CT and DT as it pertains to areas such as

- Learners’ choice on whether to take a face-to-face class or an online class
- Learners’ choice of what resource to use within a class
- Educators’ choice of what statistical models to use to analyze learner outcomes
- What groups the learners will choose to join when given the choice in a constructivist classroom

The articles cover many topics, but only a couple is related to learner choices at the level of instructional modes. Karagiannidis et al. (2008) tried to identify what resources learners wanted to use based on their instructional preference. This research is close in methodology to this study, but it fails to offer the learner a variety of modes to facilitate their learning. Radenski
(2009) tried to identify what motivational factors allowed learners to retain information. His research focuses on allowing learners to choose what, how and when they were going to learn would enhance their motivation in their learning. The result of his study was that giving the learner the choice in their own education increased their motivation to learn.

Mashakbh et al. (2013) was based on individualizing the educational experience for each learner in an engineering class. This dissertation is similar but differs in that the educator is allowing the learner to choose the preferred mode for him or herself. Mashakbh et al. created a model that allowed educators to pick the preferred multimedia mode for their learner. Understanding learners and their instructional preference is very important, but if the educator chooses the learning mode, then the power of educational choice is taken away from the learner.

The constructivist theory of education is well founded in education and there has been several books written on the best practices of its application in education (Duffy & Jonassen, 1992a; Larochelle, Bednarz, & Garrison, 1998; Wilson, 1996). The literature on this theory appears to be extensive, but research database searches as of this date resulted in no articles that encompassed constructivist theory of education, decision theory, and choice theory (see Appendix A).

Mishra and Koehler (2006) expanded on Shulman’s (1986) theory to propose Technological Pedagogical Content Knowledge (TPCK). They addressed the technology proficiency that an educator must have to be a quality educator in technology. They determined that educators make choices concerning their own education and choose what technological proficiencies they need, but they do not allow the user instructional choices within a classroom.

Although Choice Theory appears to be well founded in political sciences (Ostrom, 1998; Green & Shapiro, 1994) its possibilities have not been fully explored in education. This fundamental
theory has not been applied to learners’ options when it comes to online courses, nor has it been applied to the educational choices a learner will make within a course. The choices learners typically make are restricted to which class they wish to take. Learners enroll in a class, which may rely on either synchronous or asynchronous content delivery, typically with a schedule and set of topics set by the instructor.

*Decision Theory* is well founded in mathematics and statistics (Cyert & March, 1963; Berger, 1985). As seen from the relative literature the fundamental theory allows the individual the ability to choose what decisions they might make based on educated information. The knowledge they might gain from a specific task will help them to make future decisions. This experience is critical in making informed decisions that will allow the learner to attain the intended learning outcomes in whatever task they are attempting.

*Decision Theory and Choice Theory* appear to be correlated with the *constructivist form of education*, but the former two theories have not been applied to a computer science educational context; these theories are more often found in social and financial disciplines. Applying these two theories as well as the *constructivist theory of education* create a foundation that can be used to create a student-centered learning environment. This would allow instruction to focus on attainment of the learning objectives through a series of choices that would be based on learners’ experience. A class can be created in which modules would support the learner. The class will allow learners the opportunity to choose the way they would prefer to receive instruction. It will allow the learner to build upon their existing knowledge and make decisions that they feel will help them with a higher rate of attainment of the learning outcomes. Providing learners the opportunity to choose between the different modes of presented material, allows the learner to choose the option that may fit their needs. It may
enhance their learning and, in turn, it may influence their future educational choices.
Chapter 3. Study Design

This study explored the choices learners make when presented with a choice of multiple modes of instruction in an online module. This information may be used for creation of online modules that would be learner-centered and would provide educational choices to the learner on what their preferred instructional mode would be. Learners may find that they need more than one to properly attain the learning objectives. Providing the learner the choice of which mode(s) they have classroom material presented to them will address the different instructional preference. This will allow educators to offer a better educational experience to a larger group of learners.

Educators in CS or related degree programs from four different colleges and universities were approached and asked to participate in the research. Educators were chosen because they teach the introduction to CS or similar course at their institutions.

Each group of learners had different educators and each of the classes had different learning objectives as reflected in their syllabi.

Learners were asked to complete three learning modules. Their educator or the researcher directed the learners to the online modules. The participants completed the modules within the first three weeks of the spring 2014 semester. The learners participated on a voluntary basis. At the completion of the study the participating students’ names and unique university IDs were given to the educator of each class. Any learner who opted out of the research was given an alternative assignment that took roughly the same amount of time and effort to complete as the research project. The process followed the IRB regulations put forth by the University at Albany.
Population

Learners in a typical introduction to computer science or related courses at a two or four year U.S. college were the focus of this study. Both traditional college students (18-21 who entered college directly after high school, etc.) and non-traditional students (adults, non-matriculated, or second degree students) are typically found in such courses. This study speaks to both computer science and computer information systems majors and learners taking such courses for majors in hopes of becoming computer science or computer information systems majors.

Sample

This study includes 252 learners enrolled in introduction to computer science (or related courses) at the two- or four-year college level in four northeastern colleges. The learners were from computer science programs or related degree programs near Albany and Potsdam, New York. The institutions were selected because of their proximity to the researcher and existing professional connections to department chairs or course instructors.

Learners varied in age and demographics based largely on the nature of the institution: four-year or community college. They include traditional college students, adult learners, and high school students taking college level classes as part of their studies.

Institutions

Combinations of two- and four-year schools were invited to participate to ensure a broad representation of student demographics, prior experience, and capabilities (see Table 5).
Table 5. Institutional characteristics

<table>
<thead>
<tr>
<th>Institution</th>
<th>City</th>
<th>FTE - Undergraduates</th>
<th>CS or related degree Majors</th>
<th>Class capacity in an intro to CS or equivalent course</th>
</tr>
</thead>
<tbody>
<tr>
<td>University at Albany, SUNY</td>
<td>Albany, NY</td>
<td>17,300</td>
<td>254</td>
<td>250</td>
</tr>
<tr>
<td>The State University of New York at Potsdam</td>
<td>Potsdam, NY</td>
<td>3,988</td>
<td>98</td>
<td>28</td>
</tr>
<tr>
<td>Hudson Valley CC</td>
<td>Troy, NY</td>
<td>13,000</td>
<td>335</td>
<td>138</td>
</tr>
<tr>
<td>Adirondack CC</td>
<td>Queensbury, NY</td>
<td>2,263</td>
<td>50</td>
<td>65</td>
</tr>
</tbody>
</table>

Courses

Four participating courses were identified. They are the first courses in their institutions’ CS or similar degree and are taught in the Spring 2014 semester at nearby two or four year institutions (Table 6). The researcher also had professional connections with each of the educators.
Table 6. Number of potential participants by institution and course

<table>
<thead>
<tr>
<th>Institution</th>
<th>Name of Course</th>
<th>Participating sections</th>
<th>Projected total potential participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hudson Valley CC</td>
<td>Introduction to Computing and Information Sciences</td>
<td>5</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 unique instructors</td>
<td></td>
</tr>
<tr>
<td>University at Albany, SUNY</td>
<td>Introduction to CS</td>
<td>1</td>
<td>250</td>
</tr>
<tr>
<td>The State University of New York at Potsdam</td>
<td>Introduction to CS</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>Adirondack CC</td>
<td>Topics in Computing</td>
<td>2</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 unique instructors</td>
<td></td>
</tr>
</tbody>
</table>

Recruitment

Faculty of participating courses were contacted via email and asked whether they were willing to participate in the research. The researcher then went to each of the classes and provided an overview of the research to the learners and educators.

During the first three weeks of each college's spring semester the learners in the introduction to CS classes were asked to log into an online learning management system (LMS). When the learners entered the online class they were given a formal description of how the modules were designed. The learners were also provided a University at Albany Institutional Review Board (IRB) approved statement regarding informed consent and had the opportunity to opt out of the study without penalty.
Human subjects review

The Institutional Review Board (IRB) at the University at Albany approved the research design and materials in January 2014\(^1\). Learners were able to opt in or out of the study as the first page of the online content. If learners agreed to participate, a demographic data questionnaire was presented. Otherwise, their demographic information was not collected, but they were able to make use of the learning materials in this study in order to avoid disadvantaging non-participants.

No data was collected about the educators and no observations were made as to whether the educator followed up with the participants on the completion of the online modules.

Intervention Design

During the first three weeks of class, the researcher visited each class where the study was explained to students and they were given paper copies of the consent form; extra copies were left with the class instructor for students who were absent that day. The consent form included the directions and URL to access the online learning modules.

The researcher or the class instructor directed students to visit the learning management system (LMS) website where they could review the study, consent or decline to participate, access the learning materials, and respond to assessments. During learner interactions with the LMS, the system collected data directly via questionnaires (e.g., demographic information) and indirectly via server logs (e.g., records of number of resources accessed).

\(^1\) University at Albany, State University of New York, IRB 14X003. Faculty Supervisor: Joette Stef-Mabry.
Accessing the research site

The learners followed a two-step process:

1. they visited the LMS website for the study, and
2. they were provided with instructions to self-enroll in the LMS.

Obtaining consent

The learner was greeted with a welcome screen and a description of the research (see Figure 3) which included the researcher’s contact information as well as contact information for the faculty supervisor and the institutional review board. The learner was asked to complete a one-question survey to opt in or opt out of the research (see Figure 4).

Figure 3. Welcome to the study
Obtaining demographic information

If the learner opted to participate, he was presented with a demographic survey (see Appendix B), which allowed him to provide information about himself and his institution.

Completing learning modules

The three learning modules (see Figure 5) opened after the demographic survey was completed. Each learning module had the same structure: a statement of instructional objectives, entering behavior (pre-test), instructional procedures, and performance assessment (posttest) (see Figure 6). The modules could be completed in any order.
Instructional objectives

The learners were presented with an overview of the module and its components (see Figure 7).

The learning objectives were written to ensure that learning objectives were clear and the expectations of the learner were known.
Entering Behavior

The learners completed a pretest of learning objectives for the module. For each module a pre and posttest was required. These assessments were composed of the same questions with the order of the questions randomly selected by the LMS. The learner was not presented with the correct answer to the question when the pretest was completed. The results of the pretest identified which questions were answered correctly and which questions were not. The questions were carefully selected from various textbooks and the questions were tied to the learning objectives of the modules (see Appendix C).

When selecting questions for the assessment each question was carefully considered based on how well and completely the question addressed the specific learning objective(s) for the module. The questions had to be written broadly as not to require any unrelated knowledge. Questions were taken from a variety of test banks created as part of instructional packages developed by Prentice Hall educational resources with permission of the publisher’s representative. Various textbooks’ test banks were used for each assessment and these textbooks were not part of a specific series. The researcher chose questions based on their
content and their coverage of the learning objectives as a primary criterion. The second criterion was the generic representation of the topic so that participants regardless of institution or instructor would reasonably understand the questions.

Questions that were written in pseudocode (a plain language style of describing computer programming steps) were preferred over those written in a specific programming language, such as Java or C++. The research project assumed no prior programming knowledge and it was expected that participating instructors would be using a range of programming languages in their classes.

The process of question selection would seem to be a simple process. There are many textbooks that address introduction to computer science, but the questions also had to address the online resources’ selected for the modules. Since the online resources were not created directly to address the assessment questions, the process was challenging. Participating educators were asked to evaluate the questions chosen and their opinions about likely ability of their students to both understand and respond successfully were taken into consideration for final question selection.

**Instructional Procedure**

The learners were presented with the instructional modes for the learning objective. The researcher worked with the instructors of the courses to verify that the presented instructional modes would support the attainment of student learning objectives.

The modules were presented in an asynchronous, non-sequential manner. The learners could choose to engage the content of the module in any order they wanted. They could choose any number of instructional modes. The learner could choose to take the post assessment at any
time, but they could only take the assessment once.

For each module, five online resources were selected to reflect differing instructional modes: ways of presenting the content such as text, video, or animation. These modes were selected by evaluating the top-level search results available from a typical web search. This method of selection was intended to mimic students’ own search behaviors and thus to reflect the types of resources they might well find of their own initiative.

For example, for a search with the terms “Boolean Algebra”, many resources were returned, but based on Young (2011) most learners will only select the first or second item in search results. This is problematic pedagogically in that the first one or two resources likely will not address all of the learning objectives in the modules. In keeping with expected student behavior, the resources were chosen from the first page of search results whenever possible. The searches were restricted by file type and the researcher evaluated the results to confirm that the resource did in fact cover all of the topics in the learning module. The result of this process generated a variety of resources with each module having first page search result items including: a YouTube video, an Adobe PDF document that was rendered as a webpage, a Wikipedia web page, a Google book, and a webpage that covered the topic. Additionally, YouTube resources were selected based on duration of the video (videos must be short enough that learners could reasonably be expected to view them) and complete coverage of the topic.

Each resource covered all of the topics in the learning modules. For each resource there was the risk that more information than the learner needed to complete the module would be presented. This is the same issue that a learner would experience, if they searched the Web to find a resource on their own; they might find a resource that gives them the sought after information, but it is buried in the content of the resource because the resource was not
created with their learning objectives in mind.

When performing the searches to find resources, synonyms were used to evaluate a larger results pool and to try and reproduce learners’ information seeking behavior while attempting to find a resource (see Appendix A for search terms; associated lesson plans appear in Appendix C).

Table 7. Search terms

<table>
<thead>
<tr>
<th>Module</th>
<th>Search terms used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binary Numbers</td>
<td>Binary numbers</td>
</tr>
<tr>
<td></td>
<td>Number conversion</td>
</tr>
<tr>
<td></td>
<td>Number Systems</td>
</tr>
<tr>
<td></td>
<td>Binary</td>
</tr>
<tr>
<td>If statements</td>
<td>If Statements</td>
</tr>
<tr>
<td></td>
<td>If Statements in programming</td>
</tr>
<tr>
<td></td>
<td>Conditional Logic</td>
</tr>
<tr>
<td></td>
<td>Condition statements</td>
</tr>
<tr>
<td></td>
<td>Decision structures</td>
</tr>
<tr>
<td>Boolean Algebra</td>
<td>Boolean Algebra</td>
</tr>
<tr>
<td></td>
<td>Boolean Logic</td>
</tr>
<tr>
<td></td>
<td>Boolean Math</td>
</tr>
<tr>
<td></td>
<td>Boolean Addition</td>
</tr>
<tr>
<td></td>
<td>Boolean Subtraction</td>
</tr>
</tbody>
</table>

The default behaviors of Internet search engines and users’ web browsers are problematic for two reasons. First, learners may be logged into their Google account when they perform Web searches. The results of their searches will be influenced by the Google search engine search criteria and previously searched items. Second, learners’ search results are not reproducible: each time the searches are performed with the same search terms, the results vary slightly due to Google’s proprietary method for ranking results.
All searches for this study assumed a common starting point: a cleaned, anonymized Google Chrome browser. The history, cookies, and cached content were cleared for each search. The researcher also took care not to log into his personal Google account as not to influence the search results. All resources selected were taken from the first or second page of the search results.

When searching for the PDF documents, the File Type: PDF search constraint was added. This tailored the search results to resources that were in the form of PDF documents including PowerPoint presentations or an educator’s notes saved in PDF format.

For each module the order of the five resources varied (see Table 8).
Table 8. Resource order

<table>
<thead>
<tr>
<th>Module</th>
<th>Resource order</th>
<th>Text displayed to user</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binary Number</td>
<td>Web page</td>
<td>Binary arithmetic</td>
</tr>
<tr>
<td></td>
<td>Wikipedia</td>
<td>Binary numbers Wikipedia</td>
</tr>
<tr>
<td></td>
<td>Google Book</td>
<td>Google Book on Binary numbers</td>
</tr>
<tr>
<td></td>
<td>YouTube Video</td>
<td>Binary Arithmetic and 2s Compliment</td>
</tr>
<tr>
<td></td>
<td>PDF Document</td>
<td>PDF document for Binary numbers</td>
</tr>
<tr>
<td>If Statements</td>
<td>Web Page</td>
<td>Basic If statements</td>
</tr>
<tr>
<td></td>
<td>YouTube Video</td>
<td>Programming 104 – The IF-ELSE Statement</td>
</tr>
<tr>
<td></td>
<td>Wikipedia</td>
<td>If Statements Wikipedia</td>
</tr>
<tr>
<td></td>
<td>PDF Document</td>
<td>PDF Document for if statements</td>
</tr>
<tr>
<td></td>
<td>Google Book</td>
<td>Google Book on If statements</td>
</tr>
<tr>
<td>Boolean Algebra</td>
<td>YouTube Video</td>
<td>Boolean Algebra Part I</td>
</tr>
<tr>
<td></td>
<td>Google Book</td>
<td>Google Book on Boolean logic</td>
</tr>
<tr>
<td></td>
<td>Web Page</td>
<td>Web page detailing Boolean logic</td>
</tr>
<tr>
<td></td>
<td>PDF Document</td>
<td>PDF document for Boolean logic</td>
</tr>
<tr>
<td></td>
<td>Wikipedia</td>
<td>boolean logic Wikipedia</td>
</tr>
</tbody>
</table>

The order in which the resources were presented varied to try to alleviate order bias. Each resource appeared as a link within a content folder in the LMS. The text used to represent each link was consistent so that a learner might select any resource without irrelevant visual cues interfering with their choice.
Performance assessment

After learners reviewed as many (or few) of the resources offered, they were asked to complete a posttest on the material for the module.

The results of students’ performance on assessments were not shared with the instructors nor institutions and the final posttest grades were stored securely on the researcher’s computer, which is password protected and encrypted.

Study Timeline

Table 9. Study timeline

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposal Defense</td>
<td>November 2013</td>
</tr>
<tr>
<td>Submit IRB, University at Albany</td>
<td>November 2013</td>
</tr>
<tr>
<td>University at Albany Instructor Consent Forms</td>
<td>December 2013</td>
</tr>
<tr>
<td>SUNY Potsdam Instructor Consent Forms</td>
<td>December 2013</td>
</tr>
<tr>
<td>Hudson Valley CC Instructor Consent Forms</td>
<td>December 2013</td>
</tr>
<tr>
<td>Adirondack CC Instructor Consent Forms</td>
<td>December 2013</td>
</tr>
<tr>
<td>University at Albany Administration of Study</td>
<td>Start of Spring semester 2014</td>
</tr>
<tr>
<td>University at Potsdam Administration of Study</td>
<td>Start of Spring semester 2014</td>
</tr>
<tr>
<td>Hudson Valley CC Administration of Study</td>
<td>Start of Spring semester 2014</td>
</tr>
<tr>
<td>Adirondack CC Administration of Study</td>
<td>Start of Spring semester 2014</td>
</tr>
<tr>
<td>Data Collection</td>
<td>First week of February 2014</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>February 2014-March 2014</td>
</tr>
<tr>
<td>Report Findings</td>
<td>April 2014</td>
</tr>
<tr>
<td>Dissertation Defense</td>
<td>Late April 2014</td>
</tr>
</tbody>
</table>
Chapter 4. Analysis

This study gathered information on learners’ behavior when presented with a choice of instructional modes within an online learning management system (LMS). For each of the three learning modules related to computer science topics, learners were presented with five different options of learning materials for that topic. Learners were free to choose any, all, or none of the instructional materials and could review any of the instructional materials multiple times. When learners had decided that they had finished the module, a posttest was presented related to the module’s learning objectives.

Data Elements

Demographic, performance, and behavior data collected during participant engagement with the LMS was analyzed using exploratory data analysis techniques—such as recursive partitioning, linear modeling, and analysis of variance—to determine which factors serve as the predictors of student behavior—i.e., which factors model students’ choices of instructional modes (see Table 10).

Table 10. Description and sources of data elements

<table>
<thead>
<tr>
<th>Data Element</th>
<th>Source</th>
<th>Research question</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>First name</td>
<td>demographic form</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last name</td>
<td>demographic form</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student ID</td>
<td>demographic form</td>
<td></td>
<td>unique (within an institution) participant identifier</td>
</tr>
<tr>
<td>Gender</td>
<td>demographic form</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>demographic form</td>
<td>5</td>
<td>college in which the participant is enrolled</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>------------------</td>
<td>---</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Institution</td>
<td>demographic form</td>
<td>7</td>
<td>college in which the participant is enrolled</td>
</tr>
<tr>
<td>Number of undergraduate semesters completed</td>
<td>demographic form</td>
<td>8</td>
<td>total number of undergraduate semesters completed at any institution</td>
</tr>
<tr>
<td>Previous online class experience</td>
<td>demographic form</td>
<td>5</td>
<td>categorical variable 0,1,2,2+</td>
</tr>
<tr>
<td>For Each Module</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-assessment score</td>
<td>participant completed</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Post-assessment score</td>
<td>participant completed</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Growth score</td>
<td>calculated</td>
<td></td>
<td>difference between post-assessment score and pre-assessment score</td>
</tr>
<tr>
<td>Number of times instructional resources selected</td>
<td>LMS log</td>
<td>1, 2, 3, 4, 5, 6, 7, 8</td>
<td>count of the number of times instructional resources were accessed by the participant for this module</td>
</tr>
<tr>
<td>Mean number of times an instructional resource was selected by each student</td>
<td>calculated</td>
<td>1</td>
<td>How often were instructional resources accessed (frequency count) on</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>------------------------</td>
<td>------------------</td>
<td></td>
</tr>
<tr>
<td>Number of undergraduate semesters</td>
<td>Institutional data</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>completed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside resources used</td>
<td>survey form, self-report</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The participant’s **growth score** was calculated as the difference between post- and pre-assessment scores for each of the modules.

The **number of times instructional resources selected** was recorded for each module. This value was tracked by the LMS. The value represented how many times the instructional mode was accessed but it does not represent whether the participant surveyed all of the material in the instructional mode.

At the end of each module, participants were asked whether they had used any **outside resources** to complete the module. This was meant to see if the participant needed more information that was not provided in the instructional practices.

**Previous online class** is a categorical variable with values from the set \{0,1,2,3\}. The participant was asked whether they had completed any online classes prior to the study. This information was gathering in the opening survey.

The **number of undergraduate semesters completed** was recorded. This information was gathered from participants’ educational records and by asking the participants. This variable in conjunction with **previous online experience** may be indicative of participant choice behavior.
The variable may represent the participants’ ability to do what is necessary to be successful in order to attain the learning objectives.

**Analysis Methods**

Recursive partitioning methods (such as regression trees) (Breinman, 1984), data visualizations, and analysis of variance (ANOVA) (Brown, 1997) were used to explore the contributions of each of the available data elements (*age, gender, previous online experience, number of college semesters completed, institution type*, etc.) to model both *growth scores* for modules and *number of resources used* for each module.

Recursive partitioning determines the best predictors available in the model. The recursive partition will determine the coefficient that has the largest effect on the data. When the linear model has many interacting variables recursive partitions of the model will identify predictor variables that can be used in a linear regression. This technique, when applied to a dataset, allowed the researcher to describe characteristics of the model in more detail.

ANOVA is used when researchers want to compare the *means* of two or more groups. This process provides an instrument for the researcher to compare the means of subgroups within the data. Elemental graphics (Pruzek and Helmreich, 2008; Danielak, Pruzek, Doane, Helmreich, and Bryer, 2012) of ANOVAs were used to compare means of groups such as *age, gender, or institution*.

Additional statistical techniques and data visualizations were considered based on the characteristics of the collected data in order to provide a comprehensive exploration of the available data elements (see Appendix P, HurdDissertationEDA.Rmd).

R, an interactive statistical interface (R Core Team, 2013), was used to perform the analysis. R is
an open source statistical software application that provides a variety of packages to support
the analysis and visualization of data. R can be used either in a command-line or visual interface.
The software provides a wide variety of statistical and graphical techniques (linear and nonlinear
modeling, statistical tests, time series analysis, classification, clustering) and allows the user to
load and customize the interface with special purpose packages. The rpart (Therneau, Atkinson,
& Ripley 2013) package was used to perform recursive partitions on the data to find the best
predictor of the number of instructional resources accessed. granovaGG (Danielak et al, 2012)
was used to generate visualizations of pre-post dependant sample assessments and ANOVA
contrasts.

Data Cleaning

The LMS provided behavioral tracking data for each module as well as student responses to
assessments and surveys. Each resource in the LMS had statistical tracking enabled to identify
whether the learner accessed that particular resource.

The LMS allowed the generation of reports covering the duration of the study (January 21st
through February 15th 2014). The reports were downloaded in an Excel XML file format. Each of
these files were opened and resaved as a tab delimited file for easier use with R.

The data from each survey was downloaded separately and aligned to the gradebook data in
order to generate a single, master dataset. Response data from the LMS can only be accessed
when all report data is exported to a file and only has the results of the learners who completed
that individual survey. Data from each module’s exit survey as well as the informed consent
agree to participate survey were merged with the comprehensive gradebook data. After each
merge step, the data was checked manually to confirm that associated data were properly
attributed.

Data cleaning involved a five-stage process (see Table 11) as documented in Appendix P.

**Table 11. Stages of data cleaning**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td><strong>Convert LMS Excel reports into plain data tables</strong>&lt;br&gt;Of the 272 user accounts present in the gradebook, 16 rows were test user accounts or participants who created two accounts. The multiple accounts were left to be handled by a later script; the 4 test user rows and the 2 instructor rows were removed from the file. There were 252 unique participants in the study.&lt;br&gt;(see Appendix P: 01convertResourceFrequencyReportsToDataTables.R)</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td><strong>Merge gradebook and usage data</strong>&lt;br&gt;A unique identifier was created to match the names of the participants across all data files.&lt;br&gt;(see Appendix P: 02mergeFrequencyAndBlackboardData.R)</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td><strong>Clean additional demographic information</strong>&lt;br&gt;Participants who opted out of the research but created an account were omitted at this stage. A total of 20 observations were removed.&lt;br&gt;(see Appendix P: 03cleanDataDemographicandResource.R)</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td><strong>Merge additional demographic information</strong>&lt;br&gt;All remaining participant responses, LMS logs, and institutional data sources were merged. Fourteen participants were removed. They did not have both the opening survey and the learning modules completed. Any participant who did not complete any part of the survey or any part of the modules were removed. Participants who didn’t complete the exiting surveys for the modules were preserved.&lt;br&gt;(see Appendix P: 04mergeDemographicData.R)</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td><strong>Omit participants with missing data</strong></td>
</tr>
</tbody>
</table>
The final stage was to remove the participants who did not agree to participate or had null (missing) values for any of the tests. Participants were also removed, if they did not answer what institution or did not answer the gender questions. Finally, 199 participants who answered the opening survey, took time to take the assessments, and completed all three learning modules remained.

(see Appendix P: 05RemoveNAandBadDatafromBlackboardData.R)

One source of missing data remained in the data: participants who may not have completed the exit survey of modules. While this data is important, it is not directly used in any of the research questions. This data element was self reported and each exiting survey asked whether participants used resources other than those presented in the module.

**Characteristics of the data**

Approximately 424 learners² were invited to participate in the research project. 252 participants³ attempted to complete at least part of the online modules. Due to incomplete data (participants who did not complete all of the online modules, e.g.), 53 participants’ partial records were not used in the analysis. Learners who were not used in the study were in one of four categories:

1. They completed the opening survey but did not participate in all of the material in the modules.
2. They completed all of the modules but did not enter information in the opening survey
3. They had incomplete data in the modules or the opening survey that did not

² *Learner* denotes those enrolled in classes who may or may not have participated in this study.
³ *Participant* denotes those learners who agreed to participate in the study.
allow for proper data items to be interpreted.

4. They created an account on the LMS but they said no on the agree to participate survey.

After these learners were removed from the dataset, the sample consisted of 199 participants that were used in data analysis.

**Gender**

Of the 199 participants, 152 (76.38%) were male, 44 (22.11%) were female, and 3 (0.01%) chose not to provide this information. Compared to the Taulbee national study (2001-2012) of Bachelor’s degrees awarded in CS/CE/I (M:86.7%; F:13.3%) (Zweben S., 2011), this sample skews more female, with the exception of Potsdam, where no females participated (see Appendix D, Table 35).

**Age**

Participants ranged in age from 18 to 49 years of age with an average age of 19.6 years (see Appendix E, Figure 32).

**Institution**

154 (77.38%) participants attended a 4-year school and 45 (22.61%) attended a 2-year school.

**Previous online experience**

146 (73.36%) participants had not completed a previous online class. 29 participants (14.57%) reported completing 1 previous online class. Only 9 participants (4.52%) had completed 2 online classes. 15 participants (7.54%) had completed more than 2 online courses previously.

Appendix D, Tables 35 to 53 describe the demographic data in more detail.
Interest in study

80 participants stated that they were neutral in their interest in the research project while 96 participants either agreed or strongly agreed that they were interested in the study. Only 23 participants were not interested in the study.

College semesters completed

Previous college experience was mistakenly not included in the opening survey. This information was obtained from the professors and the institutions after the primary data collection had been completed.

Participants reported that 86 (43.21%) had completed 1 semester of college, 58 (29.15%) completed more than 3 college semesters, and 12 (6.03%) completed 2 college semesters. (see Appendix D, Table 36)

Pretest and posttest scores

The mean pre-test score ranged from 8.01 to 8.28 out of 15. Mean posttest scores ranged from 8.69 to 9.5 out of 15 (see Table 12).

<table>
<thead>
<tr>
<th>Table 12. Pretest and posttest means and medians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment</td>
</tr>
<tr>
<td>module1_binary_numbers_pretest</td>
</tr>
<tr>
<td>module1_binary_numbers_postest</td>
</tr>
<tr>
<td>module2_if_statements_pretest</td>
</tr>
<tr>
<td>module2_if_statements_posttest</td>
</tr>
<tr>
<td>module3_boolean_algebra_pretest</td>
</tr>
<tr>
<td>module3_boolean_algebra_posttest</td>
</tr>
</tbody>
</table>
Calculated data elements

Several calculated or recoded data elements were used in this analysis (see Table 13).

Table 13. Calculated and coded values

<table>
<thead>
<tr>
<th>Data item</th>
<th>Formula/ Recode</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>module1_growth</td>
<td>module1_binary_numbers_posttest - module1_binary_numbers_pretest</td>
<td></td>
</tr>
<tr>
<td>module2_growth</td>
<td>module2_if_statements_posttest - module2_if_statements_pretest</td>
<td></td>
</tr>
<tr>
<td>module3_growth</td>
<td>module3_boolean_algebra_posttest - module3_boolean_algebra_pretest</td>
<td></td>
</tr>
<tr>
<td>binary_numbers_resources_used</td>
<td>sum of the number of resources accessed on each day for module 1 (day 1 total + day 2 total + ...)</td>
<td>The variable was created for easy identification of the Binary resources accessed</td>
</tr>
<tr>
<td>IF_statements_resources_used</td>
<td>sum of the number of resources accessed on each day for module 2 (day 1 total + day 2 total + ...)</td>
<td>The variable was created for easy identification of the If statements resources accessed</td>
</tr>
<tr>
<td>boolean_algebra_resources_used</td>
<td>sum of the number of resources accessed on each day for module 3 (day 1 total + day 2 total + ...)</td>
<td>The variable was created for easy identification of the Boolean Algebra resources accessed</td>
</tr>
</tbody>
</table>

Module Growth

Module growth scores are intended to reflect participants’ learning due to engagement with each module. The posttest assessment had the same questions as the pretest but the questions were scrambled so the order was different (see Table 14).
### Table 14. Growth score summary

<table>
<thead>
<tr>
<th>Module</th>
<th>Mean</th>
<th>Median</th>
<th>Highest score</th>
<th>Lowest Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>module1_growth</td>
<td>1.46</td>
<td>1</td>
<td>12</td>
<td>-12</td>
</tr>
<tr>
<td>module2_growth</td>
<td>0.638</td>
<td>0</td>
<td>9</td>
<td>-11</td>
</tr>
<tr>
<td>module3_growth</td>
<td>1.22</td>
<td>1</td>
<td>12</td>
<td>-9</td>
</tr>
</tbody>
</table>

Visualizations of growth scores faceted by institution and gender allow for consideration of differing growth characteristics for subgroups (see Appendix M). These elemental graphics (Pruzek & Helmreich, 2008; Danielak et al, 2012) indicate that all subgroups (all genders at all institutions) demonstrated a trend toward higher posttest scores than pre-test scores in each of the three modules, suggesting that none of these subgroups were significantly disadvantaged by the study design, content, or presentation of materials. Some subgroups (e.g., those not reporting a gender) represented too few members for a linear regression to be presented.

### Recursive Partitioning

Recursive partitioning is a computationally intensive process by which available predictor variables are optimally partitioned creating a decision tree that can be used to classify observations. That is, at the first level, the variable which best (most evenly) partitions the observations is selected. In each half of the observations, the next best partitioning variable is selected. The process is repeated until each leaf of the tree represents a group too small to partition further.

Regression trees are one form of recursive partitioning used to try to find the variable(s) that
have the largest predictive value for the outcome variable and inform the creation of predictive regression models. The height of the leg reflects the relative amount of predictive value each splitting variable will have.

Once the tree has been created and all predictor variables have been identified, an analysis of the predictor variables informs the creation a new linear model. The new linear model will use the best predictor variables that appeared in the recursive partition and this new linear model will be a more accurate regression of the outcome and predictor variables.

**Linear Models**

Linear models are used to express the outcome variable in terms of the coefficients of the predictor variables. The process is used to determine statistical significance of the fitted values. It is also used to determine how much a predictor variable is affected when the outcome variable changes.

In this study there are six outcome variables:

1. `module1_growth`,
2. `module2_growth`,
3. `module3_growth`,
4. `binary_numbers_resources_used`,
5. `IF_statements_resources_used`, and
6. `boolean_algebra_resources_used`. (see Data Elements.)

The linear models of each module excluded the variables from the other modules because there was no designated order for the completion of the modules; the learner was free to complete the modules in any order, so only demographic and in-module test scores would, in general, be available to predict outcomes (e.g., for module 1: `module1_growth` or `binary_numbers_resources_used`).
Variables for age, gender, institution, semesters_in_college, and previous_online_experience may have statistical significance when applied to a single module. Only the ANOVA models

\[ boolean\_algebra\_resources\_used \sim age \] and \[ binary\_numbers\_resources\_used \sim \]

previous_online_classes return statistically significant models (see Appendix I).

**Module 1: Binary Numbers**

Based on the regression tree for the binary numbers module, previous_online_classes and module1_binary_numbers_pretest were identified as predictor variables to be included in the linear model (see Appendix H, figure 39). Initially, a linear model incorporating all predictor variables relevant to module 1 and relevant demographics was generated from which gender appeared statistically significant. Despite the complexity of this model (9 predictor variables; figure 8), the R² value adjusted for overfit due to the use of multiple predictor variables was only 0.07. In other words, only 7% of the proportion of the variance in the number of resources used in the binary numbers module was accounted for by the 9 predictor variables.

\[ binary\_numbers\_resources\_used \sim institution + gender + age + previous\_online\_classes + interested\_in\_study + semesters\_in\_college + module1\_binary\_numbers\_pretest + module1\_binary\_numbers\_posttest + external\_resources\_used\_during\_module1 \]

**Figure 8.** The “kitchen sink” linear model for predicting the number of resources used in module 1

The predictor variables indicated by the regression tree and the kitchen sink linear model was used in a new, simplified linear model for number of resources used (see Appendix I, figure 40). The simplified model accounts for 9% of the variance in the number of resources used in module 1 and is statistically significant at the p < 0.001 level.

One-way ANOVAs of module1_growth and binary_numbers_resources_used contrasted by each of age, gender, institution, previous_online_classes, and semesters_in_college groupings show
that none of the subgroups considered did significantly better or worse than the other subgroups (see Appendix N and Appendix O).

Table 15. One-way ANOVA results for module 1

<table>
<thead>
<tr>
<th>Outcome Variable</th>
<th>Contrasted by...</th>
<th>F Statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>module1_growth</td>
<td>age</td>
<td>1.10 on 20 and 178 DF</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>gender</td>
<td>0.51 on 2 and 196 DF</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>institution</td>
<td>1.85 on 3 and 195 DF</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>previous online classes</td>
<td>3.50 on 3 and 195 DF</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>semesters in college</td>
<td>0.81 on 4 and 194 DF</td>
<td>0.52</td>
</tr>
<tr>
<td>binary_numbers_resou rces_used</td>
<td>age</td>
<td>0.82 on 20 and 178 DF</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>gender</td>
<td>2.30 on 2 and 196 DF</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>institution</td>
<td>1.30 on 3 and 195 DF</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>previous online classes</td>
<td>3.38 on 3 and 195 DF</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>semesters in college</td>
<td>0.32 on 4 and 194 DF</td>
<td>0.87</td>
</tr>
</tbody>
</table>

Only previous_online_classes approaches statistical significance. However, interpretation of this result is difficult since the relative ordering of the number of previous_online_classes from lowest mean number of resources accessed to greatest number of resources accessed (also known as the contrast of binary_numbers_resources_used versus previous_online_classes) is not sequential by the number of previous_online_classes. That is, there is no apparent order to which groups showed greater growth scores or increased use of instructional resources.

The binary numbers module had the largest average growth (1.46 points on average) per learner. Dependent sample assessment plots (Pruzek and Helmreich, 2009) show that most students demonstrated statistically significant, positive growth scores (see Appendix J, figure 46).
Module 2: If Statements

Based on the regression tree for the if statements module, module2_if_statements_posttest, and previous_online_classes were selected as predictor variables to be included in the linear model for number of resources used (see Appendix H, figure 41). Initially, a linear model incorporating all predictor variables relevant to module 2 and relevant demographics was generated from which module2_if_statements_posttest and previous_online_classes appeared statistically significant. Despite the complexity of this model (9 predictor variables; see Figure 9), the R² value adjusted for overfit due to the use of multiple predictor variables was only 0.13. In other words, only 13% of the proportion of the variance in the number of resources used in the if statements module was attributable to the nine predictor variables.

\[
\text{if\_statements\_resources\_used} \sim \text{institution} + \text{gender} + \text{age} + \text{previous\_online\_classes} + \text{interested\_in\_study} + \text{semesters\_in\_college} + \text{module2\_if\_statements\_pretest} + \text{module2\_if\_statements\_posttest} + \text{external\_resources\_used\_during\_module2}
\]

**Figure 9.** The “kitchen sink” linear model for predicting the number of resources used in module 2

The predictor variables indicated by the regression tree and the kitchen sink linear model was used in a new, simplified linear model for number of resources used (see Appendix I, figure 42).

The simplified model accounts for 13% of the variance in the number of resources used in module 2 and is statistically significant at the p < 0.001 level.

One-way ANOVAs of module2_growth and if_statements_resources_used contrasted by each of age, gender, institution, previous_online_classes, and semesters_in_college groupings show that none of the subgroups performed significantly better or worse than the other subgroups (see Appendix N and Appendix O).
Table 16. One-way ANOVA results for module 2

<table>
<thead>
<tr>
<th>Outcome Variable</th>
<th>Contrasted by...</th>
<th>F Statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>module2_growth</td>
<td>Age</td>
<td>0.78 on 20 and 178 DF</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>0.57 on 2 and 196 DF</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>Institution</td>
<td>0.772 on 3 and 195 DF</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>previous_online_classes</td>
<td>0.11 on 3 and 195 DF</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>semesters_in_college</td>
<td>0.39 on 4 and 194 DF</td>
<td>0.82</td>
</tr>
<tr>
<td>if_statement_resources_used</td>
<td>Age</td>
<td>1.52 on 20 and 178 DF</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>0.96 on 2 and 196 DF</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Institution</td>
<td>1.5 on 3 and 195 DF</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>previous_online_classes</td>
<td>2.27 on 3 and 195 DF</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>semesters_in_college</td>
<td>1.27 on 4 and 194 DF</td>
<td>0.28</td>
</tr>
</tbody>
</table>

No variable is statistically significant. In the previous_online_classes ANOVA when the response was 1, the variable was statistically significant. As previously stated in the analysis of module 1 this variable is non-linear in nature, therefore it is difficult to describe.

The if statements module had the smallest mean growth score (0.64 points on average) per learner. Dependent sample assessment plots show that most students demonstrated positive growth scores (see Appendix J, figure 46).

Module 3: Boolean Algebra

Based on the regression tree for the boolean algebra module, only module3_boolean_algebra_posttest was selected as predictor variables to be included in the linear model for number of resources used (see Appendix G, figure 43). Initially, a linear model incorporating all predictor variables relevant to module 3 and relevant demographics was
generated from which `module3_if_statements_posttest`. Despite the complexity of this model (9 predictor variables; figure 10), the $R^2$ value adjusted for overfit due to the use of multiple predictor variables was only 0.11. In other words, only 11% of the proportion of the variance in the number of resources used in the if statements module was accounted for by the 9 predictor variables.

```r
boolean_algebra_resources_used ~ institution + gender + age + previous_online_classes + interested_in_study + semesters_in_college + module3_boolean_algebra_pretest + module3_boolean_algebra_posttest + external_resources_used_during_module3
```

**Figure 10.** The “kitchen sink” linear model for predicting the number of resources used in module 3

The predictor variables indicated by the regression tree and the kitchen sink linear model was used in a new, simplified linear model for number of resources used (see Appendix I, figure 44).

The simplified model accounts for 11% of the variance in the number of resources used in module 3 and is statistically significant at the $p < 0.001$ level.

One-way ANOVAs of `module3_growth` and `boolean_algebra_resources_used` contrasted by each of `age, gender, institution, previous_online_classes, and semesters_in_college` groupings show that none of the subgroups considered did significantly better or worse than the other subgroups (see Appendix N and Appendix O).
Table 17. One-way ANOVA results for module 3

<table>
<thead>
<tr>
<th>Outcome Variable</th>
<th>Contrasted by...</th>
<th>F Statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>module3_growth</td>
<td>age</td>
<td>0.70 on 20 and 178 DF</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>gender</td>
<td>1.61 on 2 and 196 DF</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>institution</td>
<td>0.65 on 3 and 195 DF</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>previous_online_classes</td>
<td>1.04 on 3 and 195 DF</td>
<td>0.38</td>
</tr>
<tr>
<td>semesters_in_college</td>
<td>0.04 on 4 and 194 DF</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>boolean_algebra_resources_used</td>
<td>age</td>
<td>2.26 on 20 and 178 DF</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>gender</td>
<td>0.54 on 2 and 196 DF</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>institution</td>
<td>1.77 on 3 and 195 DF</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>previous_online_classes</td>
<td>0.28 on 3 and 195 DF</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>semesters_in_college</td>
<td>1.89 on 4 and 194 DF</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Only the comparison of boolean_algebra_resources_used by age is statistically significant.

However, interpretation of this result is difficult since the relative ordering of the number of age from lowest mean number of resources accessed to greatest number of resources accessed (also known as the contrast of boolean_algebra_resources_used versus age) is not sequential by the age of the learner. That is, there is no apparent order to which groups showed greater growth scores or increased use of instructional resources

The boolean algebra module had the middle mean growth score (1.22 points on average) per learner. Dependant sample assessment plots show that most students demonstrated positive growth scores (see Appendix J, figure 47).
Research Questions Considered

In the following number of modes of instruction selected should be interpreted to mean the number of times any of the instructional resources within each module was accessed. That is, given five learning resources presented in module 1, the LMS reports did not distinguish between cases such as (a) accessing the first resource three times and (b) accessing three different resources. This is discussed further in the Limitations section.

What is the mean number of modes of instruction selected per module?
The number of instructional resources accessed by students was consistently low. Of five presented resources in each module, students used only 0.69 to 1.18 resources on average.

<table>
<thead>
<tr>
<th>Table 18. Mean resource use by module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binary Numbers</td>
</tr>
<tr>
<td>1.18</td>
</tr>
</tbody>
</table>
Number of Times any Resource was Accessed

One might assume that the average number of modes selected per module decreased as students completed each module (see figure 11), but learners were free to complete the modules in any order. Therefore, no order of completion should be assumed.

**Figure 11.** Number of times any resource was accessed

Do pretest scores correlate with the number of instructional modes selected by students?

**Table 19.** Correlation between pretest scores and resources used

<table>
<thead>
<tr>
<th></th>
<th>Binary Numbers *</th>
<th>If statements **</th>
<th>Boolean Algebra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s r with Pretest scores</td>
<td>-0.14 t = -2.0406, df = 197, p-value = 0.042</td>
<td>0.17 t = 2.503, df = 197, p-value = 0.013</td>
<td>0.11 t = 1.5707, df = 197, p-value = 0.118</td>
</tr>
</tbody>
</table>
In the if statement and boolean algebra modules there is a positive correlation between the number of resources used and the pretest scores. There is a negative correlation between the binary_numbers_resources_used and pretest scores, which implies that learners who had lower pretest scores did not use more resources.

**Does the number of instructional modes selected correlate with an increase in posttest scores?**

**Table 20. Correlation between posttest scores and resources used**

<table>
<thead>
<tr>
<th>Module</th>
<th>Binary Numbers ***</th>
<th>If statements ***</th>
<th>Boolean Algebra ***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s r</td>
<td>0.21</td>
<td>0.21</td>
<td>0.26</td>
</tr>
<tr>
<td>with growth scores</td>
<td>t = 2.947, df = 197, p-value = 0.004</td>
<td>t = 2.9685, df = 197, p-value = 0.003</td>
<td>t = 3.7375, df = 197, p-value = 0.000</td>
</tr>
</tbody>
</table>

There is a positive, statistically significant correlation for all three modules. As previously stated posttest scores were statistically significant in all of the linear regressions. This is verified by the recursive partition trees determining that resources_used was the largest predictor for each modules growth variable.

**Is gender correlated with the number of instructional modes selected?**

**Table 21. Correlation between gender and resources used**

<table>
<thead>
<tr>
<th>Module</th>
<th>Binary Numbers *</th>
<th>If statements</th>
<th>Boolean Algebra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s r</td>
<td>-0.15</td>
<td>-0.06</td>
<td>-0.06</td>
</tr>
<tr>
<td>with Gender</td>
<td>t = -2.1118, df = 197, p-value = 0.036</td>
<td>t = -0.8401, df = 197, p-value = 0.402</td>
<td>t = -0.8148, df = 197, p-value = 0.416</td>
</tr>
</tbody>
</table>

A statistically significant, weak negative correlation exists between gender and the number of resources used in module 1 (binary numbers).
Is age correlated with the number of instructional modes selected?

Table 22. Correlation between age and resources used

<table>
<thead>
<tr>
<th></th>
<th>Binary Numbers</th>
<th>If statements</th>
<th>Boolean Algebra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s r with Age</td>
<td>0.01</td>
<td>0.11</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>$t = 0.1765$, df = 197, p-value = 0.860</td>
<td>$t = 1.6048$, df = 197, p-value = 0.110</td>
<td>$t = 1.7154$, df = 197, p-value = 0.088</td>
</tr>
</tbody>
</table>

There is no statistically significance between age and the number of modes selected. Age does appear as a predictor in the recursive partition trees but it does not have a strong predictive value. In the regression model for module3_growth age is statistically significant, but upon further analysis the variables have 21 factors and only 2 of the 21 factors are statistically significant. Therefore the variable age is not correlated with the number of modes selected.

Is previous online class experience correlated with the number of instructional modes selected?

Table 23. Correlation between previous online classes and resources used

<table>
<thead>
<tr>
<th></th>
<th>Binary Numbers</th>
<th>If statements</th>
<th>Boolean Algebra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s r with Previous online classes</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>$t = 0.2471$, df = 197, p-value = 0.805</td>
<td>$t = 0.4526$, df = 197, p-value = 0.651</td>
<td>$t = 0.3612$, df = 197, p-value = 0.718</td>
</tr>
</tbody>
</table>

There is a small positive correlation between previous_online_classes and instructional resources used, but the values are not statistically significant for all the models. The if statements recursive tree indicated that previous_online_classes was the largest predictor of the instructional modes and the regression model with $if\_statements\_resources\_used \sim previous\_online\_classes + module2\_if\_statements\_posttest$ statistically significant at a p-value < .001. Overall the variable is not correlated with the number resources selected.
Does institution type correlate with the number of instructional modes selected?

Table 24. Correlation between institution and resources used

<table>
<thead>
<tr>
<th></th>
<th>Binary Numbers</th>
<th>If statements</th>
<th>Boolean Algebra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s r with Institution</td>
<td>0.02 t = 0.2838, df = 197, p-value = 0.777</td>
<td>-0.05 t = -0.7589, df = 197, p-value = 0.449</td>
<td>0.03 t = 0.4545, df = 197, p-value = 0.650</td>
</tr>
</tbody>
</table>

The interpretation of the correlation between institution and the numbers of resources selected is a weak analysis. The largest sample of participants came from SUNY Albany, and there were not enough participants from Hudson Valley CC and Adirondack CC to make generalized statement between 2 and 4-year schools. Institution type is not statistically significant for any of the modules.

Does the number of college semesters completed correlate with the number of instructional modes selected?

Table 25. Correlation between number of college semesters completed and resources used

<table>
<thead>
<tr>
<th></th>
<th>Binary Numbers</th>
<th>If statements *</th>
<th>Boolean Algebra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s r with College Semesters completed</td>
<td>0.007 t = 0.11, df = 197, p-value = 0.913</td>
<td>0.14 t = 2.0843, df = 197, p-value = 0.038</td>
<td>0.06 t = 0.8853, df = 197, p-value = 0.377</td>
</tr>
</tbody>
</table>

There is a positive correlation between the number of college semesters and the module 2 If statements. The other two modules have a very small positive correlation but they are not statistically significant.
Chapter 5. Discussion

Reflections on Theoretical Frameworks

How well did student behavior in these learning modules match initial expectations of learner behavior based on Choice Theory, Decision Theory, and constructivist education theory?

Choice Theory

This study explored learner behavior when given the choice of multiple instructional modes. Choice Theory would suggest that learners would be empowered by being able to choose which learning resources to use and how many to use (Glasser, 2010). One might expect learners to access multiple resources as they work to find the resources best suited their needs.

Although this study cannot determine what resources participants used within each module (due to data reporting constraints of the LMS), most participants chose fewer than a mean of 1.0 instructional modes per module, despite having five resources available in each module. Indeed, 17 participants chose to use no resources in module 1, 28 used no resources in module 2, and 39 used no resources in module 3; 10 participants used zero resources in each of the three modules. Additionally, over 75% of the students self-reported that they did not use outside resources while completing the learning modules. In other words, participants did not avail themselves of the choices presented, nor did they seek out additional instructional support.

Possible predictors of student choice behavior including gender, age, institution, and semesters completed in college were considered, but were not found to be statistically significant
predictors of whether students would choose multiple instructional modes. Choice theory suggests that experience informs the choices people make: people with greater experience are expected to make more choices and for them to be informed choices. Since learners who have a greater number of semesters in college have more experience in learning environments generally, it was expected that learners who have been through more college classes would take advantage of a greater number of the available resources, but this was not observed.

Further research is needed to determine whether students’ behavior was due to affordances of the LMS, learned behavior on the part of the participants, or to another unknown factors.

**Decision Theory**

*Decision Theory* is the process of making decisions based on the problem or situation at hand (Berger, 1985). Decisions are made based on prior experience or analyzing situational information. This study was designed so as not to lead the participants to use the resources in the modules in any specific order nor did it lead them to use any resources at all. Instead, the goal was to explore how many resources the participants would use per module of their own volition.

Ideally, one could determine whether decisions made in one module affected the decisions made in other modules. Due to the LMS reporting constraints and the design of the study there

---

4 Affordances include design, aesthetics, terminology, etc. "...the term affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used. [...] Affordances provide strong clues to the operations of things. Plates are for pushing. Knobs are for turning. Slots are for inserting things into. Balls are for throwing or bouncing. When affordances are taken advantage of, the user knows what to do just by looking: no picture, label, or instruction needed." (Norman 1988, p.9)
is no way to determine in which order the modules were completed.

This study also explored the idea that participants’ awareness of their pretest performance would influence them to use more resources to do better on the posttest, an expectation rooted in decision theory’s claim that students, given information, will make informed decisions to complete the task (Edwards, 1961). Given that the participants knew what the learning objectives were for each module, it was left to the participant to use the resources to attain the learning objectives. However, since the mean number of resources used was less than 1.0 per module and the mean growth score for all three modules is 1.11 points per module, it appears that participants did not use more resources when they scored poorly on the pretest. The unstated expectation that learners would use more resources to improve their scores might clash with learners’ expectations for engagement in an online class.

**Constructivist Education Theory**

The *constructivist education theory* argues that learners build new understanding from prior knowledge and new information. Cunningham & Duffy (1996), e.g., found that learners build their knowledge based on the resources they have around them. Therefore, in this study participants were presented with multiple possible instructional modes in each learning module and given the freedom to explore and choose their preferred resources; a freedom that learners might not have experienced in previous learning experiences.

This study explored the idea that learners who have the ability to build their knowledge by using more instructional modes would do so. However, learners used approximately one or fewer instructional modes per module. The number of instructional modes used was the largest predictor for growth scores for each of the modules, but the mean growth score was less than
2.0 points per module.

Makgato (2012) found that empowering the learner by presenting information to them would allow the learner to build their knowledge base and grow their knowledge from experience. Therefore it would be expected that participants who had previous online class experience prior to exploring the modules in this study would know from prior experience how to approach learning in an online environment; that is, how to navigate such a site and the purpose of the provided resources. Indeed, the largest predictor that was statistically significant and identified by the recursive partitioning tree for the if statements module was previous_online_experience. This also supports the findings of Wojciechowski & Palmer (2005) who found that previous online classroom experience statistically significant predictor for success in online classes: “first time students often lacked the necessary independence and time management skills needed for persistence” (p17).

**Additional findings**

Analyses show that the mean number of resources used by participants was less than approximately one resource per module. Despite this, posttest score was the most significant predictor of how many resources a participant used. In the if statements module along with posttest scores, previous_online_classes was found to be a statistically significant predictor of the number of resources used.

Participants in the study did not use all of the resources available to them when attempting the modules; they also did not have a substantial increase in growth scores (less than 2 points per module). There were few statistically significant predictors found via the ANOVA comparisons between the demographic variables (age, gender, institution, and semesters_in_college) and
resources_used or growth scores. Previous_online_classes was a predictor but it was only statistically significant for the if statements module.

Limitations

First, the student sample size could be larger and extended to include different geographical regions. This might allow generalizations about the nature of student choice regarding instructional modes.

Second, the number of modules in the study limits the range of research questions that can be addressed. Future research will speak to an entire class developed in the instructional model described in this study. This will allow the researcher to perform an extensive ANOVA on the growth scores of the modules to determine whether there is a correlation with the number of instructional modes selected. Using only three modules does not allow generalizations about whether when a learner does poorly in a module they will select more instructional modes in subsequent modules.

Third, there is a lack of assessment of the participants’ motivation to do well in the class. It can be argued that a more motivated student will do what he or she needs to do to be successful in a class (Wallace, 2007). This would mean that a more motivated student might select more modes, or he or she might use the same mode repeatedly until he or she were comfortable with the material. An instrument such as Motivated Strategies for Learning Questionnaire (MSLQ) that measures student motivation could be added to the study (Pintrich, 1993). Such an instrument was not added because this study focused on user choices rather than motivations for those choices, as a baseline for future research.

Fourth, the lack of determining student preferred method of learning within the study. This
information might be useful in determining what instructional modes to present to the learner. There could be several sets of instructional modes developed for each topic, and based on a pre-assessment of learning style of the learner; different sets of instructional modes could become available. This would limit choices that the learner may not choose because they would not fit their preferred method of learning. Neighmond (2011) expressed her concerns that educators should not cater to individual students’ needs, however she is referring to a traditional classroom where educators are face-to-face with the students and present the material in real time. Online classroom environments that use web resources allow the educator to present multiple instructional modes to the learners without catering to individual needs, but instead offering the learner the ability to choose the experience of different instructional modes.

Fifth, the modules could be completed in a synchronous order. Using ANOVA between sequential modules may offer a more detailed understanding of the choices learners make.

Sixth, a different LMS system could be used where statistical tracking logs provided finer resolution (see Issues with data collection).

Seventh, the ratio of participants from 2 and 4-year schools could be balanced. This would allow the researcher to generalize about types of institutions.

Eighth, multiple hypothesis test were computed on the same data increasing the likelihood that a statistically significant result would be discovered by chance. Since this is an exploratory study, the results should be interpreted as suggesting areas for future research and not as causal relationships amongst the variables.

Finally, the use of an LMS or similar platform that tracks whether the instructional mode was actually used would be informative. A different approach might be a tool that could record the
amount of time a learner spends on each element of the module. Such efforts are now underway with MOOCs (Anderson, 2013), but are beyond the scope and resources of this study.

**Issues with data collection**

LMS reports provided information about learners' *time on task* for each assessment. A discrepancy was found in the data where a participant answered a single question in the assessment but their *time on task* was not recorded by the LMS. Further analysis of the logged gradebook data revealed that the participant spent over 5 hours in the assessment, submitted the first three questions, and did not submit answers for the rest of the assessment, however, the report still stated that the participant spent no time on task. This discrepancy was reported to the LMS vendor. The other reports and data extracted from the LMS were sampled and the data from other reports were verified to be accurate. The LMS vendor’s help desk staff confirmed that the gradebook values and surveys were reporting accurate data.

A second bug was found with the LMS’s logging behavior and was reported to the vendor. The *statistical tracking report* generated by the LMS did not properly record which resources were used inside a folder; instead, each time a resource was used the count for every resource within the folder increased by one. For example, if a learner accessed a folder with five resources within the module and selected the first, third, and fifth resources, then all five resources in the folder would report a count of 3. Creating a test user account and selecting different permutations of the resources and running the statistical tracking reports verified this. Due to the limitation of the data from the report, it is impossible to tell which resources in each module were accessed. The research questions were concerned with the *number* of resources that were accessed, not *which* resources. This did not pose a problem for this study but is of concern for future research.
Pretest and posttest observations

Seven students had a value of 0 for either their pretest score or their posttest score. This value is indicative of an ambiguity in the data: there is no way to tell whether the learner:

- opened the test, chose not to answer any questions, and submitted the exam, or
- answered every question incorrectly.

The 0 assessment scores were kept in the data analysis because it would have been impossible to distinguish such cases. There was a second reason for keeping the zeros: it was important to apply consistent rules to the data analysis. If an assessment were exempted from the study because a participant failed to answer a question, then every assessment that failed to answer any questions would need to be removed from the study no matter what the score of the assessment.

Future research

In addition to the research implications of the study’s limitations, other research possibilities exist:

- An ethnographic study based on focus groups at the completion of the modules could be done. Participants’ could be questioned concerning resource selection, motivation, and other factors that might help to predict why they chose or didn’t choose a specific resource.
- A study could include structuring all the modules in the online class to be structured like the modules in this study. This design may allow generalized comments to be made about interactions between modules.
- The study could be repeated for different types of participants, e.g., high schools,
charter schools, or middle schools.

- The study could be performed with non-computer science majors.
- The study could be repeated and different tracking software such as Google Analytics\(^5\) could be used to improve reporting of participant behaviors. However, this type of analysis would eliminate the ability to identify individual participants because they would be identified by IP address and multiple people from the same location may have the same IP address.
- A follow up study could be repeated with the participants who enrolled in the second course in CS or a related topic. The same participants would be asked to complete different modules with the same structure and analysis of their choices could be performed to see whether there exists any recurring pattern.
- A study could include questions incorporated into the midterm or final assessments to determine whether the participants retained the information after the first three weeks of class.

**Conclusion**

Enrollment in computer science degree programs is on the rise and research has shown that educators may not be prepared to teach the new technologies that are being developed (Khumalo, 2004). Educators do not have enough time to keep current on all of the rapidly emerging technologies. The web presents an array of educational information for educators to use.

Curation of online resources for the benefit of learners is challenging: educators lack time and

\(^5\) [http://www.google.com/analytics/](http://www.google.com/analytics/)
expertise to assess the quality and scope of resources, resources varying in quality, and resources may not target the desired learning outcomes. Online learning materials are typically not designed with a specific learning objective in mind. Rather, courses exist on the web—much like one finds in brick-and-mortar institutions—but materials targeting individual learning outcomes are difficult to find.

YouTube provides a variety of topics and several of the videos can be used to support instruction. Khan University⁶, Coursera⁷, EdX⁸, edutopia⁹, and other popular online classrooms like MOOCs provide a large amount of structured information. However, most online courses do not provide information about individual student learning objectives unless you enroll in the class. Learners who want information about a specific topic may not be able to find it on the web. They may not have the skills to effectively identify relevant search terms to find a topic.

This study explored the possibility that presenting more than one instructional mode to the learner might improve learners’ attainment of learning outcomes. The study was motivated by the belief that learners, when given the choice of instructional mode, might decide to educate themselves by using more than one mode or by choosing the mode best-suited to their learning needs. However, this behavior was not observed among the study’s participants. When given the opportunity, participants used a mean of less than 1.0 instructional mode per module and had a mean growth score of less than 2.0 points per module.

Educators who take the time to create an individualized, learner-centered class may find that learners are not using multiple learning resources or instructional modes. This implies that the

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⁶ https://www.khanacademy.org/
⁷ https://www.coursera.org/
⁸ https://wwwedx.org/
⁹ http://www.edutopia.org/
time an educator spends creating the modules and curating outside resources needs to be supported by instructional design. Learners are likely to need additional training and support to effectively use the resources provided in order for them to have the ability to choose an instructional mode that best suits their learning needs. Additionally, if such use is incorporated into class assessments, learners might be encouraged to use more resources.

Further research is needed to explore factors that influence learner choices in online modules. Learners’ motivations, expectations for behavior in an online course, or anticipation of assessments may well influence learner behavior. While learner-centered online environments may afford the learner the ability to choose instructional modes, whether learners desire or can leverage such options remains to be demonstrated.
Works Cited


communications and technology (Vol. 2). Routledge.


## Appendix A. LITERATURE REVIEW

### DATABASE SEARCH RESULTS

Table 26. Results from Academic Search Complete

<table>
<thead>
<tr>
<th>Search Terms</th>
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</tr>
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<td>0</td>
<td></td>
</tr>
<tr>
<td>+ decision theory</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>+ student choice</td>
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<td></td>
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<tr>
<td>Online Course</td>
<td>1456</td>
<td></td>
</tr>
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<td>+ choice theory</td>
<td>0</td>
<td></td>
</tr>
<tr>
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<tr>
<td>+ student choice</td>
<td>3</td>
<td></td>
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**Table 27.** Results from ACM Digital Library Portal

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<td>+ choice theory</td>
<td>3</td>
<td>Preference-based decision making for personalized access to Learning Resources</td>
</tr>
<tr>
<td>+ decision theory</td>
<td>216</td>
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</tr>
<tr>
<td>+ student choice</td>
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<td>Freedom of choice as motivational factor for active learning</td>
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<td>Online Course</td>
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<td></td>
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<td>+ choice theory</td>
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<td></td>
</tr>
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<td></td>
</tr>
<tr>
<td>+ student choice</td>
<td>3</td>
<td></td>
</tr>
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<td>Count</td>
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</tr>
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<td>--------</td>
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</tr>
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</tr>
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</tr>
<tr>
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Table 29. Results from the Computer Source database (via University at Albany’s Library)

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<td>164</td>
<td></td>
</tr>
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<td>0</td>
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<td>+ decision theory</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>+ student choice</td>
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Table 30. Results from ERIC (via University at Albany’s Library)

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</tr>
<tr>
<td>+ choice theory</td>
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<td></td>
</tr>
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</tr>
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<td>+ choice theory</td>
<td>0</td>
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</tr>
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<td>+ decision theory</td>
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<td></td>
</tr>
<tr>
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<td></td>
</tr>
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Table 31. Results from ScienceDirect (via University at Albany’s Library)

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</tr>
</thead>
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<td></td>
</tr>
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<td></td>
</tr>
<tr>
<td>+ decision theory</td>
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</tr>
<tr>
<td>+ student choice</td>
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<td></td>
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<tr>
<td>Online Course</td>
<td>3095</td>
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</tr>
<tr>
<td>+ choice theory</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>+ decision theory</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>+ student choice</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B. SURVEYS

Figure 12. Opening survey

**Question 1**
What is your first name?

**Question 2**
What is your last name?

**Question 3**
What is your student ID?

**Question 4**
What college do you attend?
- University at Albany, SUNY
- University at Potsdam, SUNY
- Hudson Valley CC
- Adirondack CC

**Question 5**
What class are you enrolled in? i.e. CIS 100 or CIS 201

**Question 6**
What section are you in?

**Question 7**
Please enter the name of the professor for your class.

**Question 8**
What is your gender?
- Male
- Female
- I choose not to provide this information

**Question 9**
What is your age? (please enter a 0 if you choose not to answer this question)
QUESTION 10
How many online classes have you completed before?
○ 0
○ 1
○ 2
○ more than 2

QUESTION 11
On a scale of 1 to 5, 1 being the low and 5 being the high, please answer the question:
I am interested in this study?
Appendix C. LESSON PLAN FOR EACH MODULE

Individual lesson plan for module 1

Educator: Andrew J Hurd

Title: Module 1 Binary numbers

Subject(s): Binary numbers

Objectives:

- The learner will be able to identify a binary number
- The learner will be able to identify a bit as a 1 or 0
- The learner will be able to convert a decimal number into a binary number
- The learner will be able to identify the placeholders in a binary number and decimal numbers
- The learner will be able to convert binary numbers to decimal numbers
- The learner will be able to perform binary addition
- The learner will be able to perform binary subtraction

Materials Needed:
Online module access

Brief Description:
The learner will access the online content.
There will be a sequence of steps that the learner will follow.
The sequence is:
1) Read overview
2) Take pretest
3) 5 different modes open after the pretest
   a. Google.book
   b. Website ciss100.com
   c. Khan academy or similar video found on YouTube
   d. Powerpoint presentation found on the first page of a Google search
   e. Adobe PDF found on the first page of a Google search
4) Take posttest, this opens at the same time as the 5 different modes

Lesson:
1. The learner will access the online module.
Instructional Objectives
2. The learner will read the overview of the module.
a. The overview of this module is to learn about binary numbers and their conversion to decimal numbers. Expectations of the learner:
   ● The learner is expected to do their best in answering the questions.
   ● This material may appear in your class later in the semester.
   ● The learner will take the pretest once. After completion of the pretest the instructional modes will become available to the learner.
   ● The learner may access the modes as many times as they feel they need before they take the posttest.
   ● You may only take the posttest once.
Learning objectives of this module:
   ● The learner will be able to identify a binary number
   ● The learner will be able to identify a bit as a 1 or 0
   ● The learner will be able to convert a decimal number into a binary number
   ● The learner will be able to identify the placeholders in a binary number
   ● The learner will be able to convert binary numbers to decimal numbers

Entering Behavior
3. The learner will complete the pretest.

Instructional Procedure
4. The learner will have the choice of 5 different modes of instruction. They can access the information as many times as they wish.
a. The LMS will track the number of modes they choose and how many times they access the mode.
b. Resources:
   ● Jacob, Christian. Binary arithmetic and 2s compliment [PDF document]. Retrieved from Lecture Notes Online Website: http://pages.cpsc.ucalgary.ca/~jacob/Courses/Fall00/CPSC231/Slides/04-BitsAndArithmetic.pdf

Performance Assessment
5. The learner will complete the posttest.

Table 32. Assessment question and resources module 1
<table>
<thead>
<tr>
<th>Question</th>
<th>Resource</th>
<th>Chapter /Question</th>
<th>Learning Obj.</th>
</tr>
</thead>
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<td>3</td>
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<td>2</td>
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<td>5</td>
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<td>1, 2</td>
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</table>

Individual lesson plan for module 2

Educator: Andrew J Hurd

Title: Module 2 If statements

Subject(s): If statements

Objectives:

● The learner will be able to identify a proper if statements
● The learner will be able to identify when the if block of a conditional statement will execute
● The learner will be able to identify when the else block of a conditional statement will execute
● The learner will be able to define what a boolean value is
● The learner will be able to evaluate if/else statements
● The learner will be able to evaluate logical AND (&&) statements
● The learner will be able to evaluate logical OR (||) statements

Materials Needed:
Online module access

Brief Description:
The learner will access the online content.
There will be a sequence of steps that the learner will follow.
The sequence is:
1) Read overview
2) Take pretest
3) 5 different modes open after the pretest
   a. Google.book
   b. Website ciss100.com
   c. Popular YouTube video
   d. Microsoft Powerpoint presentation found on the first page of a Google search
   e. Adobe PDF found on the first page of a Google search
4) Take posttest, this opens at the same time as the 5 different modes

Lesson:
1. The learner will access the online module.

Instructional Objectives
2. The learner will read the overview of the module.
a. The overview of this module is to learn about logic statements.
Expectations of the learner:
   ● The learner is expected to do their best in answering the questions.
● This material may appear in your class later in the semester.
● The learner will take the pretest once. After completion of the pretest the instructional modes will become available to the learner.
● The learner may access the modes as many times as they feel they need before they take the posttest.
● You may only take the posttest once.

Learning objectives of this module:
● The learner will be able to identify a proper if statements
● The learner will be able to identify when the if block of a conditional statement will execute
● The learner will be able to identify when the else block of a conditional statement will execute
● The learner will be able to define what a boolean value is
● The learner will be able to evaluate if/else statements
● The learner will be able to evaluate logical AND (&&) statements
● The learner will be able to evaluate logical OR (||) statements

Entering Behavior
3. The learner will complete the pretest.

Instructional Procedure
4. The learner will have the choice of 5 different modes of instruction. They can access the information as many times as they wish.
   a. The LMS will track the number of modes they choose and how many times they access the mode.
   b. Resources:
      ● 2013, April 30. Programming 104 – the if-else statement. [Video file]. Retrieved from https://www.youtube.com/watch?v=s8Ehkqlvb7E

Performance Assessment
5. The learner will complete the posttest.

Table 33. Assessment and question resources module 2

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<thead>
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<th>Resource</th>
<th>Page/Question</th>
<th>Learning Obj.</th>
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Individual lesson plan for module 3

Educator: Andrew J Hurd
Title: Module 3 Boolean Algebra
Subject(s): Boolean Algebra

Objectives:
● You will be able to identify a logical AND gate
● You will be able to identify a logical OR gate
● You will be able to identify logical AND and OR truth tables
● You will be able to identify basic laws of boolean logic like commutative and associative laws
● You will be able to evaluate logical AND and OR statements
● You will be able to identify the logical NOT operator

Materials Needed:
Online module access

Brief Description:
The learner will access the online content.
There will be a sequence of steps that the learner will follow.
The sequence is:
1) Read overview
2) Take pretest
3) 5 different modes open after the pretest
   a. Google book
   b. Website: ciss100.com
   c. Popular YouTube video
   d. Microsoft PowerPoint presentation found on the first page of a Google search
   e. Adobe PDF found on the first page of a Google search
4) Take posttest, this opens at the same time as the 5 different modes

Lesson:
1. The learner will access the online module.

Instructional Objectives
2. The learner will read the overview of the module.
   a. The overview of this module is to learn about logic statements.

Expectations of the learner:
● The learner is expected to do their best in answering the questions.
● This material may appear in your class later in the semester.
● The learner will take the pretest once. After completion of the pretest the instructional modes will become available to the learner.
● The learner may access the modes as many times as they feel they need before they
take the posttest.
  
- You may only take the posttest once.

**Learning objectives of this module:**
- You will be able to identify a logical AND gate
- You will be able to identify a logical OR gate
- You will be able to identify logical AND and OR truth tables
- You will be able to identify basic laws of boolean logic like commutative and associative laws
- You will be able to evaluate logical AND and OR statements
- You will be able to identify the logical NOT operator

**Entering Behavior**
3. The learner will complete the pretest.

**Instructional Procedure**
4. The learner will have the choice of 5 different modes of instruction. They can access the information as many times as they wish.
   a. The LMS will track the number of modes they choose and how many times they access the mode.
   b. Resources:
      - Choi, K. *Boolean Algebra (Binary logic)* [PDF document]. Retrieved form Lecture Notes Online Website: http://www.cse.psu.edu/~kyusun/class/cmpen270/10s/lec/L04LogicGates.pdf

**Performance Assessment**
5. The learner will complete the posttest.

**Learning objectives**
1. You will be able to identify a logical AND gate
2. You will be able to identify a logical OR gate
3. You will be able to identify logical AND and OR truth tables
4. You will be able to identify basic laws of boolean logic like commutative and associative laws
5. You will be able to evaluate logical AND and OR statements
6. You will be able to identify the logical NOT operator

**Table 34. Assessment and question resources module 3**

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<th>Learning Obj.</th>
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93
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Appendix D. CROSS TABULATIONS

institution by gender

Figure 13. institution by gender

crosstab(institution, gender, prop.r = TRUE, prop.c = TRUE, prop.t = FALSE,
prop.chisq = FALSE, chisq = FALSE)
**Table 35.** institution by gender

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===========================================================================

96
**age by gender**

**Figure 14. age by gender**

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prop.chisq = FALSE, chisq = FALSE)
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age by previous_online_classes

Figure 15. age by previous_online_classes

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gender by semesters_in_college

Figure 16. gender by semesters_in_college

crosstab(gender, semesters_in_college, prop.r = TRUE, prop.c = TRUE, prop.t = FALSE, prop.chisq = FALSE, chisq = FALSE)
Table 38. gender by semesters_in_college

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binary_numbers_resources_used by gender

Figure 17. binary_numbers_resources_used by gender

crosstab(binary_numbers_resources_used, gender, prop.r = TRUE, prop.c = TRUE)
Table 39. binary_numbers_resources_used by gender

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binary_numbers_resources_used by age

Figure 18. binary_numbers_resources_used by age

crosstab(age, binary_numbers_resources_used, prop.r=TRUE, prop.c=TRUE)
Table 40. age by binary_numbers_resources_used

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Figure 19. binary_numbers_resources_used by institution

crosstab(binary_numbers_resources_used, institution, prop.r = TRUE, prop.c = TRUE)
Table 41. binary_numbers_resources_used by institution

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binary_numbers_resources_used by previous_online_classes

Figure 20. binary_numbers_resources_used by previous_online_classes

crosstab(binary_numbers_resources_used, previous_online_classes, prop.r = TRUE, prop.c = TRUE)
### Table 42. binary_numbers_resource_used by previous_online_classes

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binary_numbers_resources_used by semesters_in_college

Figure 21. binary_numbers_resources_used by semesters_in_college
crosstab(binary_numbers_resources_used, semesters_in_college, prop.r = TRUE, prop.c = TRUE)
Table 43. binary_numbers_resources_used by semesters_in_college

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if_statements_resources_used by gender

Figure 22. if_statements_resources_used by gender

crosstab(if_statements_resources_used, gender, prop.r = TRUE, prop.c = TRUE)
Table 44. if_statements_resources_used by gender

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117
if_statements_resources_used by age

Figure 23. if_statements_resources_used by age

crosstab(age, if_statements_resources_used, prop.r=TRUE, prop.c=TRUE)
Table 45. if_statements_resources_used by age

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120
if_statements_resources_used by institution

Figure 24. if_statements_resources_used by institution

crosstab(if_statements_resources_used, institution, prop.r = TRUE, prop.c = TRUE)
Table 46. if_statements_resources_used by institution

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if_statements_resources_used by previous_online_classes

Figure 25. if_statements_resources_used by previous_online_classes

crosstab(if_statements_resources_used, previous_online_classes, prop.r = TRUE,
         prop.c = TRUE)
Table 47. if_statements_resources_used by previous_online_classes

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<tr>
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124
if_statements_resources_used by semesters_in_college

Figure 26. if_statements_resources_used by semesters_in_college

crosstab(if_statements_resources_used, semesters_in_college, prop.r = TRUE, prop.c = TRUE)
Table 48. if_statements_resources_used by semesters_in_college

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boolean_algebra_resources_used by gender

Figure 27: boolean_algebra_resources_used by gender

crosstab(boolean_algebra_resources_used, gender, prop.r = TRUE, prop.c = TRUE)
### Table 49. boolean_algebra_resources_used by gender

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**boolean_algebra_resources_used by age**

*Figure 28.* boolean_algebra_resources_used by age

crosstab(boolean_algebra_resources_used, age, prop.r=TRUE, prop.c=TRUE)
Table 50. boolean_algebra_resources_used by age

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boolean_algebra_resources_used by institution

**Figure 29.** boolean_algebra_resources_used by institution

crosstab(boolean_algebra_resources_used, institution, prop.r = TRUE, prop.c = TRUE)
Table 51. boolean_algebra_resources_used by institution

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### boolean_algebra_resources_used by previous_online_classes

**Figure 30.** boolean_algebra_resources_used by previous_online_classes

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crosstab(boolean_algebra_resources_used, previous_online_classes, prop.r = TRUE, prop.c = TRUE)
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Table 52. boolean_algebra_resources_used by previous_online_classes
boolean_algebra_resources_used by semesters_in_college

Figure 31. boolean_algebra_resources_used by semesters_in_college

crosstab(boolean_algebra_resources_used, semesters_in_college, prop.r = TRUE, prop.c = TRUE)
Table 53. boolean_algebra_resources_used by semesters_in_college

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Appendix E. SUMMARY OF DATA ELEMENTS

Summary statistics for each data element

Figure 32. Summary of data

summary(final_Data)

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</tr>
<tr>
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<td>1st Qu. : 7.00</td>
</tr>
<tr>
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<td>Median : 10.00</td>
</tr>
<tr>
<td>Mean : 8.01</td>
<td>Mean : 9.47</td>
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<tr>
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<tr>
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<td></td>
<td>Mean : 8.05</td>
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<tr>
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<td>Median : 8.00</td>
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<table>
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<td>1st Qu. : 7.00</td>
</tr>
<tr>
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<td>Median : 10.00</td>
</tr>
<tr>
<td>Mean : 8.28</td>
<td>Mean : 9.5</td>
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<td>3rd Qu. : 12.00</td>
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<table>
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<th>module2_growth</th>
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<td>Min. : -11.00</td>
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<td>1st Qu. : -1.00</td>
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<td>Yes : 33</td>
<td>Median : 1.00</td>
<td>Median : 0.00</td>
</tr>
<tr>
<td></td>
<td>Mean : 1.46</td>
<td>Mean : 0.638</td>
</tr>
<tr>
<td></td>
<td>Min.</td>
<td>1st Qu.</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>module3_growth</td>
<td>-9.000</td>
<td>0.50</td>
</tr>
<tr>
<td>binary_numbers_resources_used</td>
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<td>0.000</td>
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<tr>
<td>boolean_algebra_resources_used</td>
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<td>0.000</td>
</tr>
</tbody>
</table>

Max. : 12.00  Max. : 9.000

Max. : 12.00  Max. : 7.00
Appendix F. RECURSIVE PARTITION TREES FOR GROWTH SCORES

Figure 33. module1_growth recursive tree
m1.part <- rpart(module1_growth ~ institution + gender + age + previous_online_classes + interested_in_study + semesters_in_college + external_resources_used_during_module1 + binary_numbers_resources_used)

print(m1.part)

plot(m1.part)
text(m1.part, use.n = TRUE)

n= 199

node), split, n, deviance, yval
   * denotes terminal node

1) root 199 1659.00 1.4620
   2) binary_numbers_resources_used< 0.5 30 296.00 0.0000
      4) semesters_in_college=2,3 12 148.70 -1.6670 *
      5) semesters_in_college=1,4,5 18 91.78 1.1110 *
   3) binary_numbers_resources_used>=0.5 16 9 1288.00 1.7220
      6) previous_online_classes=1,2,more than 2 46 160.70 0.6304 *
      7) previous_online_classes=0 12 1052.00 2.1300
   14) external_resources_used_during_module1=No 76 530.80 1.5530
      28) semesters_in_college=2,3,4 57 367.90 1.0350
         56) age>=18.5 34 188.20 0.4118 *
         57) age< 18.5 23 147.00 1.9570 *
      29) semesters_in_college=1,5 19 101.80 3.1050 *
   15) external_resources_used_during_module1=Yes 47 454.80 3.0640
      30) institution=Adirondack CC, Hudson Valley CC 11 58.18 1.2730 *
      31) institution=University at Albany, SUNY, University at Potsdam, SUNY 36
         62) semesters_in_college=3,4 9 35.56 2.2220 *
         63) semesters_in_college=2,5 27 291.90 4.0740 *
Figure 34. module2_growth recursive tree

m2.part <- rpart(module2_growth ~ institution + gender + age + previous_online_classes + interested_in_study + semesters_in_college + external_resources_used_during_module2 + if_statements_resources_used)

print(m2.part)
plot(m2.part)
text(m2.part, use.n = TRUE)

n = 199

node), split, n, deviance, yval  
  * denotes terminal node

1) root 199 1076.00 0.6382  
  2) if_statements_resources_used< 0.5 60 410.80 0.0500  
     4) external_resources_used_during_module2= 8 143.50 -1.2500 *  
     5) external_resources_used_during_module2=No,Yes 52 251.80 0.2500  
  10) institution=Adirondack CC, Hudson Valley CC 9 62.89 -0.8889 *  
     11) institution=University at Albany, SUNY, University at Potsdam, SUNY 43 174.70 0.4884  
        22) age>=20.5 8 45.50 -0.7500 *  
        23) age< 20.5 35 114.20 0.7714  
        46) interested_in_study=Neither Agree nor Disagree, Strongly Agree, Strongly disagree 19 30.53 0.1579 *  
        47) interested_in_study=Agree, Disagree 16 68.00 1.5000 *  
  3) if_statements_resources_used>=0.5 139 635.40 0.8921  
     6) if_statements_resources_used< 1.5 124 519.70 0.7742  
        12) age>=29 7 21.71 -0.4286 *  
        13) age< 29 117 487.20 0.8462  
           26) institution=University at Albany, SUNY 87 347.30 0.6667 *  
           27) institution=Adirondack CC, Hudson Valley CC, University at Potsdam, SUNY 30 129.00 1.3670  
              54) age>=18.5 20 63.80 0.9000 *  
              55) age< 18.5 10 52.10 2.3000 *  
  7) if_statements_resources_used>=1.5 15 99.73 1.8670 *

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Figure 35. module3_growth recursive tree

m3.part <- rpart(module3_growth ~ institution + gender + age + previous_online_classes + interested_in_study + semesters_in_college + external_resources_used_during_module3 + boolean_algebra_resources_used)
print(m3.part)
plot(m3.part)
text(m3.part, use.n = TRUE)

n= 199

node), split, n, deviance, yval
* denotes terminal node

1) root 199 1490.00 1.2210
   2) boolean_algebra_resources_used< 0.5 82 410.20 0.1463
      4) interested_in_study=Agree,Strongly disagree 32 95.72 -0.4062 *
      5) interested_in_study=Disagree,Neither Agree nor Disagree,Strongly Agree 50 298.50 0.5000
   10) previous_online_classes=1,2,more than 2 14 45.43 -0.4286 *
      11) previous_online_classes=0 36 236.30 0.8611 *
   3) boolean_algebra_resources_used>=0.5 117 918.90 1.9740
      6) gender=Female 30 183.00 0.9667
         12) institution=Adirondack CC,Hudson Valley CC 11 122.00 0.0000 *
         13) institution=University at Albany, SUNY 19 44.74 1.5260 *
   7) gender=Male,I choose not to provide this information. 87 695.00 2.3220
      14) interested_in_study=Agree,Neither Agree nor Disagree,Strongly disagree 63 467.00 1.9840
         28) age< 20.5 42 246.30 1.5710
            56) institution=Hudson Valley CC,University at Potsdam, SUNY 8 49.50 0.2500 *
            57) institution=Adirondack CC,University at Albany, SUNY 34 179.50 1.8820 *
   29) age>=20.5 21 199.20 2.8100
      58) age>=25 8 27.50 1.2500 *
      59) age< 25 13 140.30 3.7690 *
   15) interested_in_study=Disagree,Strongly Agree 24 202.00 3.2080 *
Appendix G. RECURSIVE PARTITION TREES FOR RESOURCES USED

Figure 36. binary_numbers_resources_used

\[
\text{m1.part} \leftarrow \text{rpart}(\text{binary_numbers_resources_used} \sim \text{institution} + \text{gender} + \text{age} + \text{previous_online_classes} + \text{interested_in_study} + \text{semesters_in_college} + \text{module1_binary_numbers_pretest} + \text{module1_binary_numbers_posttest} + \text{external_resources_used_during_module1})
\]
\[
\text{print(m1.part)}
\]
n = 199

node), split, n, deviance, yval
  * denotes terminal node

1) root 199 162.800 1.1760
   2) previous_online_classes=0,1, more than 2 190 124.400 1.1370
      4) module1_binary_numbers_pretest>=9.5 66 24.620 0.9242 *
      5) module1_binary_numbers_pretest< 9.5 124 95.250 1.2500
         10) module1_binary_numbers_posttest< 10.5 93 56.920 1.1080
             20) semesters_in_college=1,3,5 34 16.260 0.8529
                 40) age>=19.5 23 8.870 0.6957 *
                 41) age< 19.5 11 5.636 1.1820 *
            21) semesters_in_college=2,4 59 37.190 1.2540
               42) module1_binary_numbers_pretest< 6.5 30 13.870 1.0670 *
               43) module1_binary_numbers_pretest>=6.5 29 21.170 1.4480 *
         11) module1_binary_numbers_posttest>=10.5 31 30.770 1.6770
            22) external_resources_used_during_module1=Yes 9 2.000 1.0000 *
            23) external_resources_used_during_module1=No 22 22.950 1.9550
               46) interested_in_study=Neither Agree nor Disagree, Strongly disagree 10
                  4.500 1.5000 *
               47) interested_in_study=Agree, Strongly Agree 12 14.670 2.3330 *
          3) previous_online_classes=2 9 32.000 2.0000 *

plot(m1.part)
text(m1.part, use.n = TRUE)
Figure 37. if_statements_resources_used

\[ \text{m2.part} \leftarrow \text{rpart(if_statements_resources_used ~ institution + gender + age + previous_online_classes + interested_in_study + semesters_in_college + module2_if Statements_pretest + module2_if_statements_posttest + external_resources_used_during_module2)} \]

print(m2.part)
n= 199

node), split, n, deviance, yval
* denotes terminal node

1) root 199 68.270 0.7789
   2) module2_if statements_posttest< 7.5 55 17.640 0.4545
      4) interested_in_study=Disagree,Neither Agree nor Disagree,Strongly Agree,Strongly disagree 32 7.219 0.3438
         8) module2_if statements_pretest< 5.5 19 3.158 0.2105 *
         9) module2_if statements_pretest>=5.5 13 3.231 0.5385 *
      5) interested_in_study=Agree 23 9.478 0.6087
         10) module2_if statements_pretest>=6.5 8 1.500 0.2500 *
         11) module2_if statements_pretest< 6.5 15 6.400 0.8000 *
   3) module2_if statements_posttest>=7.5 144 42.640 0.9028
      6) interested_in_study=Agree,Disagree,Neither Agree nor Disagree,Strongly disagree 121 25.320 0.8512
         12) age< 18.5 32 8.469 0.7188
         24) interested_in_study=Disagree,Neither Agree nor Disagree,Strongly disagree 18 4.444 0.5556 *
         25) interested_in_study=Agree 14 2.929 0.9286 *
      13) age>=18.5 89 16.090 0.8989
         26) previous_online_classes=1 11 2.545 0.6364 *
         27) previous_online_classes=0,2,more than 2 78 12.680 0.9359
            54) semesters_in_college=2,3,5 60 8.183 0.8833 *
            55) semesters_in_college=1,4 18 3.778 1.1110 *
      7) interested_in_study=Strongly Agree 23 15.300 1.1740
         14) semesters_in_college=1,2 15 5.733 0.8667 *
         15) semesters_in_college=4,5 8 5.500 1.7500 *

plot(m2.part)
text(m2.part, use.n = TRUE)
Figure 38. boolean_algebra_resources_used

\begin{verbatim}
m3.part <- rpart(boolean_algebra_resources_used ~ institution + gender + age + previous_online_classes + interested_in_study + semesters_in_college + module3_boolean_algebra_pretest + module3_boolean_algebra_posttest + externalResources_used_during_module3)
print(m3.part)
\end{verbatim}
n= 199

node), split, n, deviance, yval
  * denotes terminal node

1) root 199 98.3000 0.6935
   2) module3_boolean_algebra_posttest< 10.5 109 53.2300 0.4862
   4) institution=Adirondack CC,University at Albany, SUNY,University at Potsdam,
      SUNY 100 48.5100 0.4300
      8) age< 23 92 33.9100 0.3913
         16) semesters_in_college=1,3,5 29 6.7590 0.2069 *
         17) semesters_in_college=2,4 63 25.7100 0.4762
         34) module3_boolean_algebra_pretest< 4.5 9 0.0000 0.0000 *
         35) module3_boolean_algebra_pretest>=4.5 54 23.3300 0.5556
            70) previous_online_classes=1,2 11 1.6360 0.1818 *
            71) previous_online_classes=0,more than 2 43 19.7700 0.6512 *
      9) age>=23 8 12.8800 0.8750 *
   5) institution=Hudson Valley CC 9 0.8889 1.1110 *
   3) module3_boolean_algebra_posttest>=10.5 90 34.7200 0.9444
   6) module3_boolean_algebra_pretest=12.5 18 4.5000 0.5000 *
   7) module3_boolean_algebra_pretest< 12.5 72 25.7800 1.0560
      14) previous_online_classes=0,2,more than 2 65 12.9800 0.9846
         28) semesters_in_college=1,3,4,5 42 7.1430 0.8571 *
         29) semesters_in_college=2 23 3.9130 1.2170 *
      15) previous_online_classes=1 7 9.4290 1.7140 *

plot(m3.part)
text(m3.part, use.n = TRUE)
## Appendix H. LINEAR MODELS

### Table 54. Linear models

<table>
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<th>Linear model</th>
<th>Description</th>
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<tr>
<td>+ gender</td>
<td></td>
</tr>
<tr>
<td>+ age</td>
<td></td>
</tr>
<tr>
<td>+ previous_online_classes</td>
<td></td>
</tr>
<tr>
<td>+ interested_in_study</td>
<td></td>
</tr>
<tr>
<td>+ semesters_in_college</td>
<td></td>
</tr>
<tr>
<td>+ module1_binary_numbers_pretest</td>
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</tr>
<tr>
<td>+ module1_binary_numbers_posttest</td>
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</tr>
<tr>
<td>+ external_resources_used_during_module1</td>
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</tr>
<tr>
<td>+ binary_numbers_resources_used</td>
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</tr>
<tr>
<td><code>module2_growth ~ institution</code></td>
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<tr>
<td>+ gender</td>
<td></td>
</tr>
<tr>
<td>+ age</td>
<td></td>
</tr>
<tr>
<td>+ previous_online_classes</td>
<td></td>
</tr>
<tr>
<td>+ interested_in_study</td>
<td></td>
</tr>
<tr>
<td>+ semesters_in_college</td>
<td></td>
</tr>
<tr>
<td>+ module2_if_statements_pretest</td>
<td></td>
</tr>
<tr>
<td>+ module2_if_statements_posttest</td>
<td></td>
</tr>
<tr>
<td>+ external_resources_used_during_module2</td>
<td></td>
</tr>
<tr>
<td>+ if_statements_resources_used</td>
<td></td>
</tr>
<tr>
<td><code>module3_growth ~ institution</code></td>
<td></td>
</tr>
<tr>
<td>+ gender</td>
<td></td>
</tr>
<tr>
<td>+ age</td>
<td></td>
</tr>
<tr>
<td>+ previous_online_classes</td>
<td></td>
</tr>
<tr>
<td>+ interested_in_study</td>
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</tr>
<tr>
<td>+ semesters_in_college</td>
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<tr>
<td>+ module3_boolean_algebra_pretest</td>
<td></td>
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<tr>
<td>+ module3_boolean_algebra_posttest</td>
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</tr>
<tr>
<td>+ external_resources_used_during_module3</td>
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</tr>
<tr>
<td>+ boolean_algebra_resources_used</td>
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</tr>
<tr>
<td><code>binary_numbers_resources_used ~ institution</code></td>
<td></td>
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<tr>
<td>+ gender</td>
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<tr>
<td>+ age</td>
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<td>Predictor Variables</td>
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<td>----------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
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<tr>
<td>if_statements_resources_used ~ institution</td>
<td>gender, age, previous_online_classes, interested_in_study, semesters_in_college, module2_if_statements_pretest, module2_if_statements_posttest, external_resources_used_during_module2</td>
</tr>
<tr>
<td>if_statements_resources_used ~ previous_online_classes</td>
<td>module2_if_statements_posttest</td>
</tr>
<tr>
<td>boolean_algebra_resources_used ~ institution</td>
<td>gender, age, previous_online_classes, interested_in_study, semesters_in_college, module3_boolean_algebra_pretest, module3_boolean_algebra_posttest, external_resources_used_during_module3</td>
</tr>
<tr>
<td>boolean_algebra_resources_used ~ institution</td>
<td>module3_boolean_algebra_pretest, module3_boolean_algebra_posttest</td>
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</tbody>
</table>

Linear regression of the predictive variables and the statistically significant variable from the original model.
Appendix I. RESULTS FROM LINEAR REGRESSIONS

Figure 39. binary_numbers_resources_used regression

```r
ddlm <- lm(binary_numbers_resources_used ~ institution + gender + age +
  previous_online_classes +
  interested_in_study + semesters_in_college + module1_binary_numbers_pretest +
  module1_binary_numbers_posttest + external_resources_used_during_module1)

summary(ddlm)
```

**Call:**
```
lm(formula = binary_numbers_resources_used ~ institution + gender +
  age + previous_online_classes + interested_in_study + semesters_in_college +
  module1_binary_numbers_pretest + module1_binary_numbers_posttest +
  external_resources_used_during_module1)
```

**Residuals:**
```
  Min   1Q Median   3Q  Max
-1.550 -0.466  -0.128  0.260 4.670
```

**Coefficients:**

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Std. Error</th>
</tr>
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<td>(Intercept)</td>
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<td>0.49158</td>
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<tr>
<td>institutionHudson Valley CC</td>
<td>0.57357</td>
<td>0.30981</td>
</tr>
<tr>
<td>institutionUniversity at Albany, SUNY</td>
<td>-0.00885</td>
<td>0.19785</td>
</tr>
<tr>
<td>institutionUniversity at Potsdam, SUNY</td>
<td>0.02333</td>
<td>0.39199</td>
</tr>
<tr>
<td>genderMale</td>
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<td>0.15756</td>
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<tr>
<td>genderI choose not to provide this information.</td>
<td>-0.12463</td>
<td>0.56914</td>
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<td>0.01042</td>
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<td>previous_online_classes2</td>
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<td>interested_in_studyDisagree</td>
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</tr>
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<td>interested_in_studyNeither Agree nor Disagree</td>
<td>0.06039</td>
<td>0.15199</td>
</tr>
<tr>
<td>interested_in_studyStrongly Agree</td>
<td>0.22181</td>
<td>0.19910</td>
</tr>
<tr>
<td>interested_in_studyStrongly disagree</td>
<td>-0.18102</td>
<td>0.35120</td>
</tr>
<tr>
<td>semesters_in_college2</td>
<td>0.43912</td>
<td>0.29674</td>
</tr>
<tr>
<td>semesters_in_college3</td>
<td>0.37755</td>
<td>0.38795</td>
</tr>
<tr>
<td>semesters_in_college4</td>
<td>0.45545</td>
<td>0.32323</td>
</tr>
<tr>
<td>semesters_in_college5</td>
<td>0.29139</td>
<td>0.32268</td>
</tr>
<tr>
<td>module1_binary_numbers_pretest</td>
<td>-0.08712</td>
<td>0.02643</td>
</tr>
<tr>
<td>Term</td>
<td>Coefficient</td>
<td>Standard Error</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------------</td>
<td>----------------</td>
</tr>
<tr>
<td>(Intercept)</td>
<td>1.80</td>
<td>0.0730</td>
</tr>
<tr>
<td>institutionHudson Valley CC</td>
<td>1.85</td>
<td>0.0658</td>
</tr>
<tr>
<td>institutionUniversity at Albany, SUNY</td>
<td>-0.04</td>
<td>0.9644</td>
</tr>
<tr>
<td>institutionUniversity at Potsdam, SUNY</td>
<td>0.06</td>
<td>0.9526</td>
</tr>
<tr>
<td>genderMale</td>
<td>-2.17</td>
<td>0.0312</td>
</tr>
<tr>
<td>genderI choose not to provide this information.</td>
<td>-0.22</td>
<td>0.8269</td>
</tr>
<tr>
<td>age</td>
<td>0.48</td>
<td>0.6303</td>
</tr>
<tr>
<td>previous online_classes1</td>
<td>-1.56</td>
<td>0.1202</td>
</tr>
<tr>
<td>previous online_classes2</td>
<td>3.01</td>
<td>0.0030</td>
</tr>
<tr>
<td>previous online_classesmore than 2</td>
<td>-0.21</td>
<td>0.8357</td>
</tr>
<tr>
<td>interested_in_studyDisagree</td>
<td>-0.19</td>
<td>0.8493</td>
</tr>
<tr>
<td>interested_in_studyNeither Agree nor Disagree</td>
<td>0.40</td>
<td>0.6916</td>
</tr>
<tr>
<td>interested_in_studyStrongly Agree</td>
<td>1.11</td>
<td>0.2668</td>
</tr>
<tr>
<td>interested_in_studyStrongly disagree</td>
<td>-0.52</td>
<td>0.6069</td>
</tr>
<tr>
<td>semesters_in_college2</td>
<td>1.48</td>
<td>0.1407</td>
</tr>
<tr>
<td>semesters_in_college3</td>
<td>0.97</td>
<td>0.3318</td>
</tr>
<tr>
<td>semesters_in_college4</td>
<td>1.41</td>
<td>0.1606</td>
</tr>
<tr>
<td>semesters_in_college5</td>
<td>0.90</td>
<td>0.3677</td>
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<td>module1_binary_numbers_pretest</td>
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<td>0.0012</td>
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<td>module1_binary_numbers_posttest</td>
<td>2.45</td>
<td>0.0154</td>
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<td>external_resources_used_during_module1No</td>
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<td>0.4791</td>
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<tr>
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<td>-0.04</td>
<td>0.9668</td>
</tr>
</tbody>
</table>

---

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.872 on 177 degrees of freedom
Multiple R-squared: 0.173,  Adjusted R-squared: 0.0746
F-statistic: 1.76 on 21 and 177 DF,  p-value: 0.0261
Figure 40. binary_numbers_resources_used regression Modified

```r
ddlm <- lm(binary_numbers_resources_used ~ gender + previous_online_classes +
            module1_binary_numbers_pretest + module1_binary_numbers_posttest)

summary(ddlm)
```

Call:
\texttt{lm(formula = binary_numbers_resources_used ~ gender + previous_online_classes +
            module1_binary_numbers_pretest + module1_binary_numbers_posttest)}

Residuals:
\begin{tabular}{rrrrrr}
Min & 1Q & Median & 3Q & Max \\
-1.569 & -0.373 & -0.091 & 0.173 & 4.696 \\
\end{tabular}

Coefficients: 
\begin{tabular}{lll}
Estimate & Std. Error & t value & Pr(>|t|) \\
\hline
(Intercept) & 1.49194 & 0.24195 & 6.17 & 4.1e-09 *** \\
genderMale & -0.36124 & 0.14997 & -2.41 & 0.0170 * \\
genderI choose not to provide this information. & -0.31038 & 0.52841 & -0.59 & 0.5576 \\
previous_online_classes1 & -0.23312 & 0.18007 & -1.29 & 0.1970 \\
previous_online_classes2 & 0.84693 & 0.29852 & 2.84 & 0.0050 ** \\
previous_online_classesmore than 2 & -0.00327 & 0.24067 & -0.01 & 0.9892 \\
module1_binary_numbers_pretest & -0.07091 & 0.02472 & -2.87 & 0.0046 ** \\
module1_binary_numbers_posttest & 0.05578 & 0.02486 & 2.24 & 0.0260 * \\
\hline
\end{tabular}

Signif. codes:  \(0 \text{****} 0.001 \text{***} 0.01 \text{**} 0.05 \text{.} 0.1 \text{ '1}' 1\)

Residual standard error: 0.867 on 191 degrees of freedom
Multiple R-squared: 0.118, Adjusted R-squared: 0.0853
F-statistic: 3.64 on 7 and 191 DF, \textit{p-value: 0.00105}
Figure 41. if_statements_resources_used regression

ddlm <- lm(if_statements_resources_used ~ institution + gender + age +
      previous_online_classes +
      interested_in_study + semesters_in_college + module2_if_statements_pretest +
      module2_if_statements_posttest + external_resources_used_during_module2)

summary(ddlm)

Call:
  lm(formula = if_statements_resources_used ~ institution + gender +
      age + previous_online_classes + interested_in_study + semesters_in_college +
      module2_if_statements_pretest + module2_if_statements_posttest +
      external_resources_used_during_module2)

Residuals:
   Min     1Q    Median     3Q    Max
-1.1191 -0.3729  0.0432  0.3021  1.5759

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)         0.13313    0.29823  0.45  0.65586
institutionHudson Valley CC  0.25566    0.19624  1.30  0.19433
institutionUniversity at Albany, SUNY  -0.01426    0.12318 -0.12  0.90795
institutionUniversity at Potsdam, SUNY   0.06787    0.24173  0.28  0.77922
genderMale         -0.07982    0.09924 -0.80  0.41885
genderI choose not to provide this information.  -0.46647    0.35399 -1.32  0.19058
age              0.00515    0.00651  0.79  0.43344
previous_online_classes1  -0.26156    0.11803 -2.21  0.02991
previous_online_classes2  -0.00865    0.19386 -0.05  0.95786
previous_online_classesmore than 2  0.09678    0.16388  0.59  0.55316
interested_in_studyDisagree  -0.26156    0.11803 -2.21  0.02991
interested_in_studyNeither Agree nor Disagree  -0.00865    0.19386 -0.05  0.95786
interested_in_studyStrongly Agree      0.19656    0.12492  1.57  0.11796
interested_in_studyStrongly disagree    0.04293    0.22092  0.19  0.84714
semesters_in_college2      0.10104    0.18870  0.54  0.59290
semesters_in_college3      0.19550    0.24494  0.80  0.41885
semesters_in_college4      0.29636    0.20286  1.46  0.14782
semesters_in_college5      0.17845    0.20534  0.87  0.38626
module2_if_statements_pretest  -0.01043    0.01987 -0.52  0.59991
module2_if_statements_posttest    0.06629    0.01809  3.68  0.00031
external_resources_used_during_module2No  0.03168    0.12354  0.25  0.80346
external_resources_used_during_module2Yes  -0.16110    0.15600 -1.03  0.29901

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genderMale       -0.80  0.42232
genderI choose not to provide this information. -1.32  0.18928
age               0.79  0.42920
previous_online_classes1     -2.22  0.02796 *
previous_online_classes2        -0.04  0.96447
previous_online_classesmore than 2     0.59  0.55558
interested_in_studyDisagree       -0.96  0.33648
interested_in_studyNeither Agree nor Disagree -0.92  0.35665
interested_in_studyStrongly Agree   1.57  0.11738
interested_in_studyStrongly disagree  0.19  0.84615
semesters_in_college2            0.54  0.59299
semesters_in_college3            0.80  0.42584
semesters_in_college4            1.46  0.14582
semesters_in_college5            0.87  0.38602
module2_if_statements_pretest      -0.53  0.60022
module2_if_statements_posttest     3.66  0.00033 ***
external_resources_used_during_module2No  0.26  0.79794
external_resources_used_during_module2Yes -1.03  0.30317

---
Signif. codes:   0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.547 on 177 degrees of freedom
Multiple R-squared: 0.224, Adjusted R-squared: 0.132
F-statistic: 2.44 on 21 and 177 DF, p-value: 0.000861
**Figure 42. If_statements_resources_used regression Modified**

```r
ddlm <- lm(if_statements_resources_used ~ previous_online_classes + module2_if_statements_posttest)
summary(ddlm)
```

**Call:**

```r
lm(formula = if_statements_resources_used ~ previous_online_classes + module2_if_statements_posttest)
```

**Residuals:**

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>1Q</th>
<th>Median</th>
<th>3Q</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1.0477</td>
<td>-0.4515</td>
<td>0.0704</td>
<td>0.2476</td>
<td>2.1295</td>
</tr>
</tbody>
</table>

**Coefficients:**

|                          | Estimate | Std. Error | t value | Pr(>|t|) |
|--------------------------|----------|------------|---------|----------|
| (Intercept)              | 0.2801   | 0.1241     | 2.26    | 0.025    |
| previous_online_classes1 | -0.1885  | 0.1136     | -1.66   | 0.099    |
| previous_online_classes2 | -0.0403  | 0.1905     | -0.21   | 0.833    |
| previous_online_classesmore than 2 | 0.2003 | 0.1504 | 1.33 | 0.184 |
| module2_if_statements_posttest | 0.0590 | 0.0131 | 4.52 | 1.1e-05 |

```r
(Intercept) *previous_online_classes1  .
previous_online_classes2
previous_online_classesmore than 2
module2_if_statements_posttest  ***
```

---

**Signif. codes:** `0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1`

**Residual standard error:** 0.555 on 194 degrees of freedom
**Multiple R-squared:** 0.126, **Adjusted R-squared:** 0.108
**F-statistic:** 6.99 on 4 and 194 DF, **p-value:** 2.83e-05
**Figure 43. boolean_algebra_resources_used regression**

```r
ddlm <- lm(boolean_algebra_resources_used ~ institution + gender + age + previous_online_classes + interested_in_study + semesters_in_college + module3_boolean_algebra_pretest + module3_boolean_algebra_posttest + external_resources_used_during_module3)

summary(ddlm)
```

**Call:**
```
lm(formula = boolean_algebra_resources_used ~ institution + gender + age + previous_online_classes + interested_in_study + semesters_in_college + module3_boolean_algebra_pretest + module3_boolean_algebra_posttest + external_resources_used_during_module3)
```

**Residuals:**
```
Min 1Q Median 3Q Max
-1.3021 -0.4216 -0.0443 0.3147 2.9905
```

**Coefficients:**
```
            Estimate Std. Error   t value   Pr(>|t|)
(Intercept) -0.53369   0.35406 -1.51     0.13
institutionHudson Valley CC  0.32722   0.23746  1.38     0.17
institutionUniversity at Albany, SUNY  0.03328   0.15000  0.22     0.82
institutionUniversity at Potsdam, SUNY  0.28315   0.29348  0.96     0.34
genderMale -0.11419   0.11965 -0.97     0.34
genderI choose not to provide this information. -0.37985   0.43353 -0.87     0.38
age           0.01227   0.00792  1.56     0.12
previous_online_classes1  0.00165   0.14308  0.01     0.99
previous_online_classes2  0.26333   0.23819  1.10     0.27
previous_online_classesmore than 2 -0.08316   0.20014 -0.41     0.68
interested_in_studyDisagree  0.03615   0.19778  0.18     0.86
interested_in_studyNeither Agree nor Disagree  0.06872   0.11551  0.59     0.56
interested_in_studyStrongly Agree  0.13434   0.15104  0.89     0.37
interested_in_studyStrongly disagree -0.02354   0.26872 -0.09     0.93
semesters_in_college2  0.34331   0.22189  1.55     0.12
semesters_in_college3 -0.03375   0.28870 -0.12     0.90
semesters_in_college4  0.12013   0.24817  0.49     0.63
semesters_in_college5  0.26718   0.24234  1.10     0.27
module3_boolean_algebra_pretest -0.02825   0.02064 -1.37     0.17
module3_boolean_algebra_posttest  0.08671   0.01914  4.57   <0.0001
external_resources_used_during_module3No  0.15481   0.12867  1.21     0.23
external_resources_used_during_module3Yes  0.18683   0.16767  1.11     0.27
```
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<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
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<td>institutionUniversity at Potsdam, SUNY</td>
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<td>0.34</td>
</tr>
<tr>
<td>genderMale</td>
<td>-0.95</td>
<td>0.34</td>
</tr>
<tr>
<td>genderI choose not to provide this information.</td>
<td>-0.88</td>
<td>0.38</td>
</tr>
<tr>
<td>age</td>
<td>1.55</td>
<td>0.12</td>
</tr>
<tr>
<td>previous_online_classes1</td>
<td>0.01</td>
<td>0.99</td>
</tr>
<tr>
<td>previous_online_classes2</td>
<td>1.11</td>
<td>0.27</td>
</tr>
<tr>
<td>previous_online_classesmore than 2</td>
<td>-0.42</td>
<td>0.68</td>
</tr>
<tr>
<td>interested_in_studyDisagree</td>
<td>0.18</td>
<td>0.86</td>
</tr>
<tr>
<td>interested_in_studyNeither Agree nor Disagree</td>
<td>0.59</td>
<td>0.55</td>
</tr>
<tr>
<td>interested_in_studyStrongly Agree</td>
<td>0.89</td>
<td>0.37</td>
</tr>
<tr>
<td>interested_in_studyStrongly disagree</td>
<td>-0.09</td>
<td>0.93</td>
</tr>
<tr>
<td>semesters_in_college2</td>
<td>1.55</td>
<td>0.12</td>
</tr>
<tr>
<td>semesters_in_college3</td>
<td>-0.12</td>
<td>0.91</td>
</tr>
<tr>
<td>semesters_in_college4</td>
<td>0.48</td>
<td>0.63</td>
</tr>
<tr>
<td>semesters_in_college5</td>
<td>1.10</td>
<td>0.27</td>
</tr>
<tr>
<td>module3_boolean_algebra_pretest</td>
<td>-1.37</td>
<td>0.17</td>
</tr>
<tr>
<td>module3_boolean_algebra_posttest</td>
<td>4.53</td>
<td>1.1e-05 ***</td>
</tr>
<tr>
<td>external_resources_used_during_module3No</td>
<td>1.20</td>
<td>0.23</td>
</tr>
<tr>
<td>external_resources_used_during_module3Yes</td>
<td>1.11</td>
<td>0.27</td>
</tr>
</tbody>
</table>

---
Signif. codes:  
  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1

Residual standard error: 0.665 on 177 degrees of freedom
Multiple R-squared: 0.204,  Adjusted R-squared: 0.11
F-statistic: 2.17 on 21 and 177 DF,  p-value: 0.00353
Figure 44. boolean_algebra_resources_used regression Modified

ddlm <- lm(boolean_algebra_resources_used ~ module3_boolean_algebra_posttest + institution + module3_boolean_algebra_pretest)

summary(ddlm)

Call:
  lm(formula = boolean_algebra_resources_used ~ module3_boolean_algebra_posttest + institution + module3_boolean_algebra_pretest)

Residuals:
  Min     1Q    Median     3Q    Max
-1.208 -0.490  -0.011  0.253  3.225

Coefficients:            Estimate   Std. Error   t value
(Intercept)              0.0841      0.1879      0.45
module3_boolean_algebra_posttest  0.0860      0.0185      4.66
institutionHudson Valley CC  0.3722      0.2072      1.80
institutionUniversity at Albany, SUNY  0.0248      0.1353      0.18
institutionUniversity at Potsdam, SUNY  0.3344      0.2796      1.20
module3_boolean_algebra_pretest  -0.0323      0.0199     -1.63

Pr(>|t|)
  (Intercept)      0.655
module3_boolean_algebra_posttest  5.8e-06    ***
institutionHudson Valley CC      0.074
institutionUniversity at Albany, SUNY       0.855
institutionUniversity at Potsdam, SUNY       0.233
module3_boolean_algebra_pretest       0.105
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.663 on 193 degrees of freedom
Multiple R-squared:  0.137,  Adjusted R-squared:  0.115
F-statistic: 6.14 on 5 and 193 DF,  p-value: 2.66e-05
Appendix J. DEPENDENT SAMPLE ASSESSMENT PLOTS

Figure 45. module1_dependant sample plot

Summary Statistics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>199.000</td>
</tr>
<tr>
<td>post mean</td>
<td>8.688</td>
</tr>
<tr>
<td>pre mean</td>
<td>8.050</td>
</tr>
<tr>
<td>mean(D = post - pre)</td>
<td>0.638</td>
</tr>
<tr>
<td>SD(D)</td>
<td>2.331</td>
</tr>
<tr>
<td>Effect Size</td>
<td>0.274</td>
</tr>
<tr>
<td>r(post, pre)</td>
<td>0.685</td>
</tr>
<tr>
<td>r(post + pre, D)</td>
<td>0.112</td>
</tr>
<tr>
<td>Lower 95% Confidence Interval</td>
<td>0.312</td>
</tr>
<tr>
<td>Upper 95% Confidence Interval</td>
<td>0.964</td>
</tr>
<tr>
<td>t (D-bar)</td>
<td>3.862</td>
</tr>
<tr>
<td>df.t</td>
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</tr>
<tr>
<td>p-value (t-statistic)</td>
<td>0.000</td>
</tr>
</tbody>
</table>
**Figure 46.** module2_dependant sample plot

![Dependent Sample Assessment Plot]

<table>
<thead>
<tr>
<th>Summary Statistics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>199.000</td>
</tr>
<tr>
<td>post mean</td>
<td>9.497</td>
</tr>
<tr>
<td>pre mean</td>
<td>8.276</td>
</tr>
<tr>
<td>mean(D = post - pre)</td>
<td>1.221</td>
</tr>
<tr>
<td>SD(D)</td>
<td>2.743</td>
</tr>
<tr>
<td>Effect Size</td>
<td>0.445</td>
</tr>
<tr>
<td>r(post, pre)</td>
<td>0.636</td>
</tr>
<tr>
<td>r(post + pre, D)</td>
<td>0.096</td>
</tr>
<tr>
<td>Lower 95% Confidence Interval</td>
<td>0.838</td>
</tr>
<tr>
<td>Upper 95% Confidence Interval</td>
<td>1.605</td>
</tr>
<tr>
<td>t (D-bar)</td>
<td>6.279</td>
</tr>
<tr>
<td>df.t</td>
<td>198.000</td>
</tr>
<tr>
<td>p-value (t-statistic)</td>
<td>0.000</td>
</tr>
</tbody>
</table>
**Figure 47.** module3_dependant sample plot

<p>| | | |</p>
<table>
<thead>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>199.000</td>
<td></td>
</tr>
<tr>
<td>post mean</td>
<td>9.497</td>
<td></td>
</tr>
<tr>
<td>pre mean</td>
<td>8.276</td>
<td></td>
</tr>
<tr>
<td>mean(D = post - pre)</td>
<td>1.221</td>
<td></td>
</tr>
<tr>
<td>SD(D)</td>
<td>2.743</td>
<td></td>
</tr>
<tr>
<td>Effect Size</td>
<td>0.445</td>
<td></td>
</tr>
<tr>
<td>r(post, pre)</td>
<td>0.636</td>
<td></td>
</tr>
<tr>
<td>r(post + pre, D)</td>
<td>0.096</td>
<td></td>
</tr>
<tr>
<td>Lower 95% Confidence Interval</td>
<td>0.838</td>
<td></td>
</tr>
<tr>
<td>Upper 95% Confidence Interval</td>
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<td>p-value (t-statistic)</td>
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<td></td>
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</table>
Appendix K. ENHANCED SCATTER PLOT OF SELECTED VARIABLES

Figure 48. Enhanced scatter plot
Appendix L. ENHANCED SCATTER PLOT OF ADDITIONAL VARIABLES

Figure 49. Enhanced scatter plot
Appendix M. GROWTH SCORES FACETED BY GENDER AND INSTITUTION

Figure 50. Faceted gender vs. institution vs. module 1 growth scores
Figure 51. Faceted gender vs. institution vs. module 2 growth scores
Figure 52. Faceted gender vs. institution vs. module 3 growth scores
Appendix N. ANOVA BY GROWTH SCORE

ANOVA module1_growth and age

Figure 53. One-way ANOVA module1_growth and age
working_data <- final_Data
response <- working_data[, "module1_growth"]
group <- factor(working_data[, "age"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)
group group.size group.mean trimmed.mean contrast variance standard.deviation
17 33 5.00 -7.46 NA NA
19 45 4.00 -4.46 NA NA
21 49 3.00 -2.46 2.00 1.41
11 26 0.00 0.00 -1.46 3.00 1.73
14 30 0.00 0.00 -1.46 NA NA
18 44 0.00 0.00 -1.46 NA NA
6 21 0.61 1.25 -0.85 17.31 4.16
1 0 0.64 0.43 -0.83 1.25 1.12
8 23 1.00 1.00 -0.46 8.00 2.83
15 31 1.00 1.00 -0.46 NA NA
16 32 2.00 2.00 0.54 NA NA
4 19 1.28 1.22 -0.18 6.14 2.48
13 28 1.50 1.50 0.04 4.50 2.12
10 32 3.00 3.00 0.54 NA NA
9 24 2.17 2.00 0.70 4.17 2.04
3 18 2.20 1.71 0.74 9.92 3.15
17 35 3.50 3.50 2.04 0.50 0.71
20 47 4.00 4.00 2.54 NA NA
10 25 5.00 5.00 3.54 NA NA

group.size
17
1
19
1
21
2
11
3
14
1
18
1
6
18
1
11
8
2
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13
2
5
25
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8
12
2
16
1
9
6
3
49
2
2
The following groups are likely to be overplotted

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<th>Contrast</th>
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<td>2.00</td>
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<td></td>
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<td>18</td>
<td>2.20</td>
<td>0.74</td>
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</table>

Below is a linear model summary of your input data

Call:
lm(formula = score ~ group, data = owp$data)

Residuals:
  Min    1Q  Median    3Q   Max
-12.611 -1.638  -0.279   1.721  9.796

Coefficients:
             Estimate Std. Error  t value  Pr(>|t|)
(Intercept)  0.6364      0.8684   0.730   0.465
group17     2.8636      2.2140   1.290   0.198
group18     1.5677      0.9610   1.630   0.105
group19     0.6423      0.9435   0.660   0.497
group20     1.0036      1.0421   0.960   0.337
group21    -0.0253     1.1023   -0.022   0.982
group22     1.3636     1.3383    1.020   0.310
group23     0.3636      2.2140   0.160   0.870
group24     1.5303      1.4618   1.050   0.297
group25     4.3636      3.0083   1.450   0.149
group26    -0.6364     1.8760   -0.340   0.735
group27     1.3636      2.2140   0.620   0.539
group28     0.8636      2.2140   0.390   0.697
group30    -0.6364     3.0083   -0.210   0.833
group31     0.3636      3.0083   0.120   0.904
<p>| | | | | |</p>
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<td>0.651</td>
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<td>3.0083</td>
<td>-2.21</td>
<td>0.029 *</td>
</tr>
<tr>
<td>group44</td>
<td>-0.6364</td>
<td>3.0083</td>
<td>-0.21</td>
<td>0.833</td>
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<tr>
<td>group45</td>
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<td>3.0083</td>
<td>-1.21</td>
<td>0.228</td>
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<td>3.0083</td>
<td>1.12</td>
<td>0.265</td>
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<tr>
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<td>-1.6364</td>
<td>2.2140</td>
<td>-0.74</td>
<td>0.461</td>
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</tbody>
</table>

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Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.88 on 178 degrees of freedom
Multiple R-squared: 0.11, Adjusted R-squared: 0.0102
F-statistic: 1.1 on 20 and 178 DF, p-value: 0.351
ANOVA module1_growth and gender

Figure 54. One-way ANOVA module1_growth and gender
working_data <- final_Data  #subset(final_Data, gender == 'Male' | gender == 'Female')
response <- working_data[, "module1_growth"]
group <- factor(working_data[, "gender"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>I choose not to provide this information.</td>
<td>0.00</td>
</tr>
<tr>
<td>1</td>
<td>Female</td>
<td>1.30</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>1.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>contrast variance standard.deviation group.size</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
  Min       1Q   Median       3Q      Max
 -13.539  -1.539  -0.539    1.461   10.461

Coefficients:
                          Estimate   Std. Error   t value
(Intercept)               1.295       0.438       2.96
groupMale                 0.244       0.497       0.49
groupI choose not to provide this information.  1.000       1.000       1.00

Pr(>|t|)    
(Intercept)               0.0034 **
groupMale                 0.6239
groupI choose not to provide this information.  0.4553

---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.9 on 196 degrees of freedom
Multiple R-squared: 0.00515,   Adjusted R-squared: -0.005
F-statistic: 0.507 on 2 and 196 DF,  p-value: 0.603
ANOVA module1growth and institution

Figure 55. One-way ANOVA module1growth and Institution
working_data <- final_Data
response <- working_data[, "module1_growth"]
group <- factor(working_data[, "institution"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
</tr>
</thead>
<tbody>
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<td>0.25</td>
<td>0.80</td>
<td>-1.21</td>
<td>7.40</td>
</tr>
<tr>
<td>Adirondack CC</td>
<td>0.83</td>
<td>0.53</td>
<td>-0.63</td>
<td>5.22</td>
</tr>
<tr>
<td>University at Albany, SUNY</td>
<td>1.69</td>
<td>1.53</td>
<td>0.22</td>
<td>8.82</td>
</tr>
<tr>
<td>University at Potsdam, SUNY</td>
<td>2.14</td>
<td>1.80</td>
<td>0.68</td>
<td>11.48</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
  Min    1Q  Median    3Q   Max
  -13.687 -1.687  -0.687  1.961  10.313

Coefficients:
                         Estimate Std. Error t value Pr(>|t|)
(Intercept)               0.828      0.534   1.55    0.12
groupHudson Valley CC     -0.578      0.896  -0.64    0.52
groupUniversity at Albany, SUNY | 0.859 | 0.584   1.47    0.14
groupUniversity at Potsdam, SUNY | 1.315 | 1.211   1.09    0.28

Residual standard error: 2.88 on 195 degrees of freedom
Multiple R-squared: 0.0276, Adjusted R-squared: 0.0127
F-statistic: 1.85 on 3 and 195 DF, p-value: 0.14
ANOVA module1_growth and previous_online_classes

Figure 56. One-way ANOVA module1_growth and previous_onlines_classes
working_data <- final_Data
response <- working_data[, "module1_growth"]
group <- factor(working_data[, "previous_online_classes"])
granovagg.lm(response, group = group)

By-group summary statistics for your input data (ordered by group means)
group mean trimmed.mean contrast variance standard.deviation
4 more than 2  -0.27  -0.22  -1.73  2.07  1.44
2          1  0.62   0.68  -0.84  3.82  1.95
3          2  1.22   1.00  -0.24  4.44  2.11
1          0  1.82   1.72  0.36  9.68  3.11

group.size
4        15
2        29
3         9
1       146

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
     Min      1Q  Median      3Q     Max
-13.822 -1.822 -0.222  1.779  10.178

Coefficients:          Estimate Std. Error t value Pr(>|t|)
(Intercept)          1.822     0.235    7.75  5e-13 ***
group1               -1.201     0.578   -2.08   0.0389 *
group2               -0.600     0.976   -0.61   0.5396
more than 2          -2.089     0.770   -2.71   0.0073 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.84 on 195 degrees of freedom
Multiple R-squared:  0.0511, Adjusted R-squared:  0.0365
F-statistic: 3.5 on 3 and 195 DF,  p-value: 0.0165
ANOVA module1\_growth and semesters\_in\_college

Figure 57. One-way ANOVA module1\_growth and semesters\_in\_college

Contrast coefficients based on group means
working_data <- final_Data
response <- working_data[, "module1_growth"]
group <- factor(working_data[, "semesters_in_college"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
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<td>0.00</td>
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<tr>
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<td>1.67</td>
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<td>0.00</td>
<td>10.82</td>
<td>3.29</td>
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</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
   Min      1Q  Median      3Q     Max
-13.465  -1.810  -0.465   1.535  10.535

Coefficients:  

| Estimate | Std. Error | t value | Pr(>|t|) |
|----------|------------|---------|----------|
| (Intercept) | 2.000 | 0.875 | 2.29     | 0.023 * |
| group2 | -0.535 | 0.929 | -0.58    | 0.565   |
| group3 | -1.417 | 1.211 | -1.17    | 0.243   |
| group4 | -1.031 | 1.014 | -1.02    | 0.310   |
| group5 | -0.190 | 0.954 | -0.20    | 0.843   |

---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.9 on 194 degrees of freedom
Multiple R-squared: 0.0164, Adjusted R-squared: -0.00385
F-statistic: 0.81 on 4 and 194 DF, p-value: 0.52
ANOVA module2\_growth and age

Figure 58. One-way ANOVA module2\_growth and age
```r
working_data <- final_Data
response <- working_data[, "module2_growth"]
group <- factor(working_data[, "age"])
granovagg.lw(response, group = group)

By-group summary statistics for your input data (ordered by group means)

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<th>variance</th>
<th>standard.deviation</th>
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group.size

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The following groups are likely to be overplotted

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<th>group.mean</th>
<th>contrast</th>
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<td>1.36</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
lm(formula = score ~ group, data = owp$data)

Residuals:
  Min 1Q Median    3Q  Max
-10.18 -1.06   0.00  1.24   8.00

Coefficients:
  Estimate Std. Error t value Pr(>|t|)
(Intercept)  -0.818     0.711   -1.15   0.251
  group17     0.318      1.812     0.18   0.861
  group18     1.879      0.786     2.39   0.018 *
  group19     1.818      0.772     2.35   0.020 *
  group20     1.338      0.853     1.57   0.118
  group21     0.818      0.902     0.91   0.366
  group22     0.818      1.095     0.75   0.456
  group23     1.818      1.812     1.00   0.317
  group24     1.152      1.196     0.96   0.337
  group25     2.818      2.462     1.14   0.254
  group26     2.818      1.535     1.84   0.068 .
  group27     1.818      1.812     1.00   0.317
  group28     0.318      1.812     0.18   0.861
  group30     1.818      2.462     0.74   0.461
  group31    -1.182      2.462    -0.48   0.632
  group32     2.818      2.462     1.14   0.254
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<th>Value2</th>
<th>Value3</th>
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</thead>
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<td>2.462</td>
<td>0.33</td>
<td>0.740</td>
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<tr>
<td>group47</td>
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<td>0.74</td>
<td>0.461</td>
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<tr>
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<td>1.812</td>
<td>-0.10</td>
<td>0.920</td>
</tr>
</tbody>
</table>

---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2.36 on 178 degrees of freedom
Multiple R-squared: 0.0808, Adjusted R-squared: -0.0225
F-statistic: 0.782 on 20 and 178 DF,  p-value: 0.733
ANOVA module2_growth and gender

Figure 59. One-way ANOVA module2_growth and gender
working_data <- final_Data  #subset(final_Data, gender == 'Male' | gender == 'Female')
response <- working_data[, "module2_growth"]

By-group summary statistics for your input data (ordered by group means)

    group  group.mean trimmed.mean
1  Female      0.52         0.50
2    Male      0.70         0.64

contrast variance standard.deviation group.size
1  -0.67            4.77          2.38
2  -0.67            4.33          2.08

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
    Min     1Q Median     3Q    Max
-11.697 -1.523 -0.523  1.303  8.303

Coefficients:          Estimate Std. Error t value
(Intercept)              0.523     0.352    1.48
groupMale                0.175     0.400    0.44

F-statistic: 0.57 on 2 and 196 DF,  p-value: 0.566
ANOVA module2_growth and institution

Figure 60. One-way ANOVA module2_growth and Institution
working_data <- final_Data
response <- working_data[, "module2_growth"]
group <- factor(working_data[, "institution"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
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<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
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</thead>
<tbody>
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<td>5.50</td>
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<tr>
<td>University at Albany, SUNY</td>
<td>0.57</td>
<td>0.53</td>
<td>-0.07</td>
<td>5.51</td>
</tr>
<tr>
<td>1 Adirondack CC</td>
<td>0.45</td>
<td>0.42</td>
<td>-0.19</td>
<td>5.76</td>
</tr>
<tr>
<td>4 University at Potsdam, SUNY</td>
<td>1.57</td>
<td>1.60</td>
<td>0.93</td>
<td>2.62</td>
</tr>
</tbody>
</table>

standard.deviation group.size

|    |     |     |     |
| 1  | 2.40 | 29  |
| 3  | 2.35 | 147 |
| 2  | 2.34 | 16  |
| 4  | 1.62 | 7   |

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
  Min 1Q Median 3Q Max
-11.571 -1.571 -0.448 1.429 8.429

Coefficients:

|            | Estimate | Std. Error | t value | Pr(>|t|) |
|------------|----------|------------|---------|---------|
| (Intercept)| 0.448    | 0.434      | 1.03    | 0.30    |
| groupHudson Valley CC | 0.739      | 0.727      | 1.02    | 0.31    |
| groupUniversity at Albany, SUNY | 0.123      | 0.474      | 0.26    | 0.80    |
| groupUniversity at Potsdam, SUNY | 1.123      | 0.983      | 1.14    | 0.25    |

Residual standard error: 2.34 on 195 degrees of freedom
Multiple R-squared: 0.0117, Adjusted R-squared: -0.00347
F-statistic: 0.772 on 3 and 195 DF, p-value: 0.511
ANOVA module2_growth and previous_online_classes

Figure 61. One-way ANOVA module2_growth and previous_online_classes
working_data <- final_data
response <- working_data[, "module2_growth"]
group <- factor(working_data[, "previous_online_classes"])
granovagg.lw(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
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<tr>
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<th>group.mean</th>
<th>trimmed.mean</th>
<th>variance</th>
<th>standard.deviation</th>
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<td>4 more than 2</td>
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<td>0.64</td>
<td>0.04</td>
<td>5.82</td>
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<tr>
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<td>0.78</td>
<td>0.86</td>
<td>0.14</td>
<td>1.69</td>
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</tbody>
</table>

group.size
2          | 29         |
4          | 15         |
1          | 146        |
3          | 9          |

Below is a linear model summary of your input data

Call:
lm(formula = score ~ group, data = owp$data)

Residuals:
  Min 1Q Median 3Q Max
-11.678 -1.414 -0.414 1.322 8.322

Coefficients:
     Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.6781     0.1942   3.49   0.00059 ***
group1       -0.264     0.4771  -0.55   0.58028

Residual standard error: 2.35 on 195 degrees of freedom
Multiple R-squared: 0.00136,   Adjusted R-squared: -0.0136
F-statistic: 0.114 on 3 and 195 DF,  p-value: 0.952
ANOVA module2_growth and semesters_in_college

Figure 62. One-way ANOVA module2_growth and semesters_in_college

One-way ANOVA displaying 5 groups

Contrast coefficients based on group means

F = 0.39
working_data <- final_Data
response <- working_data[, "module2_growth"]
group <- factor(working_data[, "semesters_in_college"])

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
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<td>6.99</td>
<td>2.64</td>
</tr>
<tr>
<td>3</td>
<td>0.92</td>
<td>1.00</td>
<td>0.28</td>
<td>3.72</td>
<td>1.93</td>
</tr>
<tr>
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<td>1.00</td>
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</table>

The following groups are likely to be overplotted

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<th>contrast</th>
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<tr>
<td>3</td>
<td>0.92</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:

    Min     1Q  Median     3Q    Max
  -11.628 -1.379  0.379  1.372  8.094

Coefficients:

| Estimate | Std. Error | t value | Pr(>|t|) |
|----------|------------|---------|---------|
| (Intercept) | 1.0000 | 0.7072 | 1.41 | 0.16 |
| group2 | -0.3721 | 0.7511 | -0.50 | 0.62 |
| group3 | -0.0833 | 0.9791 | -0.09 | 0.93 |
| group4 | -0.0938 | 0.8198 | -0.11 | 0.91 |
| group5 | -0.6207 | 0.7714 | -0.80 | 0.42 |

Residual standard error: 2.35 on 194 degrees of freedom
Multiple R-squared: 0.00796, Adjusted R-squared: -0.0125
F-statistic: 0.389 on 4 and 194 DF, p-value: 0.816
ANOVA module3_growth and age

Figure 63. One-way ANOVA module3_growth and age
```r
working_data <- final_Data
response <- working_data[, "module3_growth"]
group <- factor(working_data[, "age"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

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<th>trimmed.mean</th>
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The following groups are likely to be overplotted

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</tr>
<tr>
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<td>44</td>
<td>3.00</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
lm(formula = score ~ group, data = owp$data)

Residuals:
   Min    1Q  Median    3Q   Max
-10.00 -1.49   0.00   1.50   9.62

Coefficients:
               Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.0909 0.84020 0.11  0.914
group17  1.4091  2.1422  0.66  0.512
group18  0.9091  0.9298  0.98  0.330
group19  1.3517  0.9129  1.48  0.140
group20  0.3891  1.0083  0.39  0.700
group21  1.6869  1.8665  1.58  0.116
group22  2.2841  1.2949  1.76  0.079
group23  2.4891  2.1422  1.12  0.262
group24  1.9091  1.4143  1.35  0.179
group25  4.9091  2.9107  1.69  0.093.
<table>
<thead>
<tr>
<th>group</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>group26</td>
<td>1.5758</td>
<td>1.8151</td>
<td>0.87</td>
<td>0.386</td>
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</tr>
<tr>
<td>group27</td>
<td>3.4091</td>
<td>2.1422</td>
<td>1.59</td>
<td>0.113</td>
<td></td>
</tr>
<tr>
<td>group28</td>
<td>-0.5909</td>
<td>2.1422</td>
<td>-0.28</td>
<td>0.783</td>
<td></td>
</tr>
<tr>
<td>group30</td>
<td>2.9091</td>
<td>2.9107</td>
<td>1.00</td>
<td>0.319</td>
<td></td>
</tr>
<tr>
<td>group31</td>
<td>-1.0909</td>
<td>2.9107</td>
<td>-0.37</td>
<td>0.708</td>
<td></td>
</tr>
<tr>
<td>group32</td>
<td>0.9091</td>
<td>2.9107</td>
<td>0.31</td>
<td>0.755</td>
<td></td>
</tr>
<tr>
<td>group33</td>
<td>-0.0909</td>
<td>2.9107</td>
<td>-0.03</td>
<td>0.975</td>
<td></td>
</tr>
<tr>
<td>group44</td>
<td>2.9091</td>
<td>2.9107</td>
<td>1.00</td>
<td>0.319</td>
<td></td>
</tr>
<tr>
<td>group45</td>
<td>-1.0909</td>
<td>2.9107</td>
<td>-0.37</td>
<td>0.708</td>
<td></td>
</tr>
<tr>
<td>group47</td>
<td>-0.0909</td>
<td>2.9107</td>
<td>-0.03</td>
<td>0.975</td>
<td></td>
</tr>
<tr>
<td>group49</td>
<td>0.4091</td>
<td>2.1422</td>
<td>0.19</td>
<td>0.849</td>
<td></td>
</tr>
</tbody>
</table>

---

Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.79 on 178 degrees of freedom
Multiple R-squared:  0.0724, Adjusted R-squared:  -0.0318
F-statistic: 0.695 on 20 and 178 DF,  p-value: 0.828
ANOVA module3_growth and gender

Figure 64. One-way ANOVA module3_growth and gender
By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>0.57</td>
<td>0.75</td>
</tr>
<tr>
<td>I choose not to provide this information.</td>
<td>1.33</td>
<td>1.33</td>
</tr>
<tr>
<td>Male</td>
<td>1.41</td>
<td>1.16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
<th>group.size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.65</td>
<td>5.93</td>
<td>2.43</td>
</tr>
<tr>
<td>3</td>
<td>0.11</td>
<td>2.33</td>
<td>1.53</td>
</tr>
<tr>
<td>2</td>
<td>0.19</td>
<td>7.99</td>
<td>2.83</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
\( \text{lm(formula = score \sim group, data = owp$data)} \)

Residuals:
\[ \begin{array}{ccccc} 
\text{Min} & \text{1Q} & \text{Median} & \text{3Q} & \text{Max} \\
-9.568 & -1.488 & -0.408 & 1.592 & 10.592 \\
\end{array} \]

Coefficients:
\[ \begin{array}{cccc}
\text{Estimate} & \text{Std. Error} & \text{t value} & \text{Pr(>|t|)} \\
(\text{Intercept}) & 0.568 & 0.412 & 1.38 \\
groupMale & 0.840 & 0.468 & 1.79 \\
groupI choose not to provide this information. & 0.765 & 1.32 & 0.47 \\
\end{array} \]

\[ \begin{array}{c}
\text{Pr(>|t|)} \\
0.170 \\
0.074 . \\
0.640 \\
\end{array} \]

---

Signif. codes:  \( 0 \ '***' 0.001 '***' 0.01 '**' 0.05 '*' 0.1 ' ' 1 \)

Residual standard error: 2.74 on 196 degrees of freedom
Multiple R-squared: 0.0162, Adjusted R-squared: 0.00613
F-statistic: 1.61 on 2 and 196 DF,  p-value: 0.202
ANOVA module3_growth and institution

Figure 65. One-way ANOVA module3_growth and institution
working_data <- final_Data
response <- working_data[, "module3_growth"]
group <- factor(working_data[, "institution"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adirondack CC</td>
<td>0.59</td>
<td>0.74</td>
<td>-0.63</td>
<td>9.68</td>
</tr>
<tr>
<td>University at Potsdam, SUNY</td>
<td>1.14</td>
<td>0.80</td>
<td>-0.08</td>
<td>11.81</td>
</tr>
<tr>
<td>University at Albany, SUNY</td>
<td>1.31</td>
<td>1.08</td>
<td>0.09</td>
<td>7.24</td>
</tr>
<tr>
<td>Hudson Valley CC</td>
<td>1.56</td>
<td>1.80</td>
<td>0.34</td>
<td>5.06</td>
</tr>
</tbody>
</table>

standard.deviation group.size
| 1 | 3.11 | 29 |
| 4 | 3.44 | 7  |
| 3 | 2.69 | 147|
| 2 | 2.25 | 16 |

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
  Min  1Q Median  3Q Max
-9.586 -1.574 -0.313 1.687 10.687

Coefficients:

                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                   0.586      0.511 1.15   0.25
groupHudson Valley CC         0.976      0.857 1.14   0.26
groupUniversity at Albany, SUNY 0.727      0.559 1.30   0.20
groupUniversity at Potsdam, SUNY 0.557     1.158 0.48   0.63

Residual standard error: 2.75 on 195 degrees of freedom
Multiple R-squared: 0.00996, Adjusted R-squared: -0.00528
F-statistic: 0.654 on 3 and 195 DF, p-value: 0.582
ANOVA module3_growth and previous_online_classes

Figure 66. One-way ANOVA module3_growth and previous_online_classes
working_data <- final_Data
response <- working_data[, "module3_growth"]
group <- factor(working_data[, "previous_online_classes"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>0.44</td>
<td>0.29</td>
<td>-0.78</td>
<td>3.28</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0.66</td>
<td>0.63</td>
<td>-0.57</td>
<td>6.31</td>
</tr>
<tr>
<td>4 more than 2</td>
<td>0.80</td>
<td>0.89</td>
<td>-0.42</td>
<td>5.74</td>
<td>2.40</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1.42</td>
<td>1.24</td>
<td>0.20</td>
<td>8.16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>group.size</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
lm(formula = score ~ group, data = owp$data)

Residuals:
   Min      1Q  Median      3Q     Max
-10.425  -1.435  -0.425   1.575   10.575

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
(Intercept)              1.425     0.227   6.28 2.2e-09 ***
group1                   -0.769     0.558  -1.38   0.17
group2                   -0.980     0.942  -1.04   0.30
groupmore than 2         -0.625     0.744  -0.84   0.40
---
Signif. codes:  < ***  0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.74 on 195 degrees of freedom
Multiple R-squared:  0.0157, Adjusted R-squared:  0.000577
F-statistic: 1.04 on 3 and 195 DF,  p-value: 0.377
ANOVA module3_growth and semesters_in_college

Figure 67. One-way ANOVA module3_growth and semesters_in_college
working_data <- final_Data
response <- working_data[, "module3_growth"]
group <- factor(working_data[, "semesters_in_college"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th></th>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>1.08</td>
<td>1.00</td>
<td>-0.14</td>
<td>2.63</td>
<td>1.62</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1.09</td>
<td>1.00</td>
<td>-0.13</td>
<td>4.29</td>
<td>2.07</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>1.12</td>
<td>1.25</td>
<td>-0.10</td>
<td>5.02</td>
<td>2.44</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1.23</td>
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<td>0.01</td>
<td>8.72</td>
<td>2.95</td>
</tr>
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<td>1.03</td>
<td>0.09</td>
<td>9.13</td>
<td>3.02</td>
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</tbody>
</table>

group.size
<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>3</td>
<td>12</td>
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<tr>
<td>1</td>
<td>11</td>
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<tr>
<td>4</td>
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<td>2</td>
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</tr>
<tr>
<td>5</td>
<td>58</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
  Min  1Q  Median  3Q  Max
  -10.233 -1.701 -0.233 1.729 10.690

Coefficients:
  Estimate Std. Error t value Pr(>|t|)
(Intercept) 1.09091  0.83534  1.31   0.19
group2    0.14165  0.88716  0.16   0.87
group3   -0.00758  1.15648 -0.01   0.99
group4    0.03409  0.96833  0.04   0.97
group5    0.21944  0.91112  0.24   0.81

Residual standard error: 2.77 on 194 degrees of freedom
Multiple R-squared: 0.000794, Adjusted R-squared: -0.0198
F-statistic: 0.0385 on 4 and 194 DF,  p-value: 0.997
Appendix O. ANOVA BY RESOURCES USED

binary_numbers_resources_used ~ age

Figure 68. One-way ANOVA binary_numbers_resources_used and age

```
working_data <- final_Data
response <- working_data[, "binary_numbers_resources_used"]
group <- factor(working_data[, "age"])
granovagg.1w(response, group = group)
```

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
</tr>
</thead>
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<td>0.00</td>
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<td>NA</td>
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<tr>
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<td>0.50</td>
<td>-0.68</td>
<td>0.50</td>
<td>0.71</td>
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<tr>
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<td>0.83</td>
<td>-0.34</td>
<td>0.50</td>
<td>0.71</td>
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</tr>
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<td>-0.18</td>
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<td>-0.18</td>
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<td>1.00</td>
<td>-0.18</td>
</tr>
<tr>
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<td>27</td>
<td>2.00</td>
<td>2.00</td>
<td>0.82</td>
</tr>
<tr>
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<td>44</td>
<td>3.00</td>
<td>3.00</td>
<td>1.82</td>
</tr>
</tbody>
</table>

The following groups are likely to be overplotted

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>1.00</td>
<td>-0.18</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>2</td>
<td>17</td>
<td>1.00</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>20</td>
<td>1.00</td>
<td>-0.18</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>9</td>
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<td>1.00</td>
<td>-0.18</td>
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</tr>
<tr>
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<td>-0.18</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
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<td>1.00</td>
<td>-0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>31</td>
<td>1.00</td>
<td>-0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>32</td>
<td>1.00</td>
<td>-0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>33</td>
<td>1.00</td>
<td>-0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>47</td>
<td>1.00</td>
<td>-0.18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
     Min      1Q  Median      3Q     Max
-1.328 -0.328  0.050  0.167  5.672

Coefficients: Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.00e+00  2.76e-01   3.62   0.00038 ***
group17     -2.87e-15  7.04e-01  -0.00     1.00000

group18     2.24e-01  3.05e-01    0.74   0.46326

group19     3.28e-01  3.00e-01    1.09   0.27566

group20     -2.19e-15  3.31e-01  -0.00     1.00000

group21     -1.67e-01  3.50e-01   -0.48   0.63482

group22     2.50e-01  4.25e-01    0.59   0.55742

group23     1.00e+00  7.04e-01    1.42   0.15701

group24     -3.11e-15  4.65e-01  -0.00     1.00000

group25     -2.23e-15  9.56e-01  -0.00     1.00000

group26     3.33e-01  5.96e-01    0.56   0.57680

group27     1.00e+00  7.04e-01    1.42   0.15701

group28     -5.00e-01  7.04e-01   -0.71   0.47826

group29     -3.74e-15  9.56e-01  -0.00     1.00000

group30     -1.94e-15  9.56e-01  -0.00     1.00000

group31     -1.65e-15  9.56e-01  -0.00     1.00000

group32     -1.42e-15  9.56e-01  -0.00     1.00000

group33     2.00e+00  9.56e-01    2.09   0.03786 *
group34     -1.00e+00  9.56e-01  -1.05   0.29699

group35     -2.48e-15  9.56e-01   -0.00     1.00000

group36     -2.65e-15  7.04e-01  -0.00     1.00000

---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.915 on 178 degrees of freedom
Multiple R-squared:  0.0842,   Adjusted R-squared:  -0.0187
F-statistic: 0.818 on 20 and 178 DF,  p-value: 0.69

binary_numbers_resources_used ~ gender

Figure 69. One-way ANOVA binary_numbers_resources_used and gender
working_data <- final_Data
response <- working_data[, "binary_numbers_resources_used"]
group <- factor(working_data[, "gender"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>2 Male</td>
<td>1.11</td>
<td>1.00</td>
</tr>
<tr>
<td>1 Female</td>
<td>1.43</td>
<td>1.21</td>
</tr>
</tbody>
</table>

contrast variance standard.deviation group.size

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>-0.18</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>-0.07</td>
<td>0.64</td>
<td>0.80</td>
</tr>
<tr>
<td>1</td>
<td>0.26</td>
<td>1.46</td>
<td>1.21</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
  Min 1Q Median 3Q Max
-1.432 -0.432 -0.105 -0.105 5.568

Coefficients:

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>1.432</td>
<td>0.136</td>
<td>10.54</td>
</tr>
<tr>
<td>groupMale</td>
<td>-0.327</td>
<td>0.154</td>
<td>-2.12</td>
</tr>
<tr>
<td>groupI choose not to provide this information.</td>
<td>-0.432</td>
<td>0.538</td>
<td>-0.80</td>
</tr>
</tbody>
</table>

Pr(>|t|)

|                     | Pr(>|t|) |
|---------------------|---------|
| (Intercept)         | <2e-16  *** |
| groupMale           | 0.036 *  |
| groupI choose not to provide this information. | 0.423 |

Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1

Residual standard error: 0.901 on 196 degrees of freedom
Multiple R-squared: 0.0229, Adjusted R-squared: 0.013
F-statistic: 2.3 on 2 and 196 DF, p-value: 0.103
binary_numbers_resources_used ~ institution

Figure 70. One-way ANOVA binary_numbers_resources_used and institution
working_data <- final_Data
response <- working_data[, "binary_numbers_resources_used"]
group <- factor(working_data[, "institution"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adirondack CC</td>
<td>1.03</td>
<td>1.0</td>
<td>-0.14</td>
<td>0.46</td>
</tr>
<tr>
<td>University at Albany, SUNY</td>
<td>1.16</td>
<td>1.0</td>
<td>-0.02</td>
<td>0.89</td>
</tr>
<tr>
<td>University at Potsdam, SUNY</td>
<td>1.29</td>
<td>1.0</td>
<td>0.11</td>
<td>0.57</td>
</tr>
<tr>
<td>Hudson Valley CC</td>
<td>1.56</td>
<td>1.4</td>
<td>0.39</td>
<td>0.93</td>
</tr>
</tbody>
</table>

standard.deviation group.size
| 1 | 0.68  | 29 |
| 3 | 0.94  | 147|
| 4 | 0.76  | 7  |
| 2 | 0.96  | 16 |

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
  Min 1Q Median 3Q Max
-1.563 -0.156 -0.156 -0.034 5.844

Coefficients:
  Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.034     0.168   6.16 4.2e-09 ***
groupHudson Valley CC  0.528     0.282   1.87  0.063 .
groupUniversity at Albany, SUNY  0.122     0.184   0.66  0.508
  groupUniversity at Potsdam, SUNY  0.251     0.381   0.66  0.511
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 . ’ 0.1 ‘ ’ 1

Residual standard error: 0.905 on 195 degrees of freedom
Multiple R-squared:  0.0191, Adjusted R-squared:  0.00402
F-statistic: 1.27 on 3 and 195 DF,  p-value: 0.287
binary_numbers_resources_used ~ previous_online_classes

Figure 71. One-way ANOVA binary_numbers_resources_used and previous_online_classes
working_data <- final_Data
response <- working_data[, "binary_numbers_resources_used"]
group <- factor(working_data[, "previous_online_classes"], levels = 1:4)
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.00</td>
<td>1.00</td>
<td>0.24</td>
<td>0.28</td>
<td>0.53</td>
</tr>
<tr>
<td>4</td>
<td>1.07</td>
<td>1.00</td>
<td>0.11</td>
<td>0.50</td>
<td>0.70</td>
</tr>
<tr>
<td>1</td>
<td>1.18</td>
<td>1.05</td>
<td>0.01</td>
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<td>2.00</td>
<td>1.43</td>
<td>0.82</td>
<td>4.00</td>
<td>2.00</td>
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</tbody>
</table>

group.size
<p>| | | | | | |</p>
<table>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
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<tr>
<td>4</td>
<td>15</td>
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<tr>
<td>3</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
  Min 1Q Median 3Q Max
-1.185 -0.185 -0.185 0.069 5.000

Coefficients:
  Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.1849    0.0737   16.07  <2e-16 ***
group1     -0.2539    0.1811   -1.40      0.1626
 group2     0.8151    0.3060     2.66      0.0084 **
groupmore than 2 -0.1183    0.2416   -0.49      0.6250
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.891 on 195 degrees of freedom
Multiple R-squared: 0.0494, Adjusted R-squared: 0.0348
F-statistic: 3.38 on 3 and 195 DF, p-value: 0.0194
binary_numbers_resources_used $\sim$ semesters_in_college

Figure 72. One-way ANOVA binary_numbers_resources_used and semesters_in_college

Contrast coefficients based on group means
working_data <- final_Data
response <- working_data[, "binary_numbers_resources_used"]
group <- factor(working_data[, "semesters_in_college"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.91</td>
<td>0.86</td>
<td>-0.27</td>
<td>0.49</td>
<td>0.70</td>
</tr>
<tr>
<td>3</td>
<td>1.08</td>
<td>1.12</td>
<td>-0.09</td>
<td>0.45</td>
<td>0.67</td>
</tr>
<tr>
<td>5</td>
<td>1.17</td>
<td>1.06</td>
<td>0.00</td>
<td>0.78</td>
<td>0.88</td>
</tr>
<tr>
<td>4</td>
<td>1.19</td>
<td>1.05</td>
<td>0.01</td>
<td>0.74</td>
<td>0.86</td>
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<td>1.22</td>
<td>1.00</td>
<td>0.05</td>
<td>1.00</td>
<td>1.00</td>
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<table>
<thead>
<tr>
<th>group.size</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>3 12</td>
</tr>
<tr>
<td>5 58</td>
</tr>
<tr>
<td>4 32</td>
</tr>
<tr>
<td>2 86</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
   Min     1Q   Median     3Q    Max
-1.221 -0.221 -0.188  0.083  5.779

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.9090     0.2750   3.300 0.0011 **
group2      0.3121     0.2922   1.071 0.2876
group3      0.1741     0.3811   0.460 0.6481
group4      0.2781     0.3191   0.871 0.3841
group5      0.2631     0.3000   0.880 0.3817
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.913 on 194 degrees of freedom
Multiple R-squared: 0.00654,  Adjusted R-squared: -0.0139
F-statistic: 0.319 on 4 and 194 DF,  p-value: 0.865

219
if_statements_resources_used ~ age

Figure 73. One-way ANOVA if_statements_resources_used and age
working_data <- final_Data
response <- working_data[, "if_statements_resources_used"]
group <- factor(working_data[, "age"])
granovagg.lw(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th></th>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
</tr>
</thead>
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<td>0.00</td>
<td>-0.78</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
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<td>0.50</td>
<td>-0.28</td>
<td>0.50</td>
<td>0.71</td>
</tr>
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<tr>
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<td>0.71</td>
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<td>0.59</td>
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<td>-0.02</td>
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<td>0.10</td>
<td>0.41</td>
<td>0.64</td>
</tr>
<tr>
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<td>19</td>
<td>0.89</td>
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<td>0.11</td>
<td>0.24</td>
<td>0.49</td>
</tr>
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<td>1.00</td>
<td>0.22</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
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<td>1.00</td>
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<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>14</td>
<td>30</td>
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<td>1.00</td>
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<td>NA</td>
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group.size
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<td>16</td>
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</tr>
<tr>
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</tbody>
</table>
The following groups are likely to be overplotted

<p>| | | | | |</p>
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<tr>
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<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
   Min 1Q Median 3Q Max
  -1.000 -0.500  0.115  0.327  1.500

Coefficients:   Estimate Std. Error   t value Pr(>|t|)
    (Intercept)  0.6364     0.1725       3.69   0.0003 ***
group17       -0.1364     0.4399      -0.31    0.7569
group18       0.0371      0.1909       0.19    0.8461
group19       0.2489      0.1874       1.33    0.1860
group20       0.1236      0.2070       0.60    0.5512
group21      -0.1364     0.2190      -0.62    0.5343
group22       0.2386      0.2659       0.90    0.3707
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<tr>
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<th>0.4399</th>
<th>3.10</th>
<th>0.0022 **</th>
</tr>
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<tbody>
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<td>0.0303</td>
<td>0.2904</td>
<td>0.10</td>
<td>0.9170</td>
</tr>
<tr>
<td>Group 25</td>
<td>1.3636</td>
<td>0.5977</td>
<td>2.28</td>
<td>0.0237 *</td>
</tr>
<tr>
<td>Group 26</td>
<td>0.3636</td>
<td>0.3727</td>
<td>0.98</td>
<td>0.3306</td>
</tr>
<tr>
<td>Group 27</td>
<td>0.3636</td>
<td>0.4399</td>
<td>0.83</td>
<td>0.4095</td>
</tr>
<tr>
<td>Group 28</td>
<td>-0.1364</td>
<td>0.4399</td>
<td>-0.31</td>
<td>0.7569</td>
</tr>
<tr>
<td>Group 30</td>
<td>0.3636</td>
<td>0.5977</td>
<td>0.61</td>
<td>0.5437</td>
</tr>
<tr>
<td>Group 31</td>
<td>0.3636</td>
<td>0.5977</td>
<td>0.61</td>
<td>0.5437</td>
</tr>
<tr>
<td>Group 32</td>
<td>0.3636</td>
<td>0.5977</td>
<td>0.61</td>
<td>0.5437</td>
</tr>
<tr>
<td>Group 33</td>
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<td>0.5977</td>
<td>0.61</td>
<td>0.5437</td>
</tr>
<tr>
<td>Group 44</td>
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<td>0.5977</td>
<td>0.61</td>
<td>0.5437</td>
</tr>
<tr>
<td>Group 45</td>
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<td>-1.06</td>
<td>0.2884</td>
</tr>
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<td>0.5977</td>
<td>0.61</td>
<td>0.5437</td>
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<tr>
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<td>1.96</td>
<td>0.0512 *</td>
</tr>
</tbody>
</table>

---

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.572 on 178 degrees of freedom
Multiple R-squared: 0.146, Adjusted R-squared: 0.0503
F-statistic: 1.52 on 20 and 178 DF,  p-value: 0.0777
if\_statements\_resources\_used \sim \text{gender}

Figure 74. One-way ANOVA if statements resources used and gender
working_data <- final_Data
response <- working_data[, "if_statements_resources_used"]
group <- factor(working_data[, "gender"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>I choose not to provide this information.</td>
<td>0.33</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>0.78</td>
</tr>
<tr>
<td>1</td>
<td>Female</td>
<td>0.82</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
<th>group.size</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>-0.45</td>
<td>0.33</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>0.00</td>
<td>0.37</td>
<td>152</td>
</tr>
<tr>
<td>1</td>
<td>0.04</td>
<td>0.25</td>
<td>44</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:  
  Min    1Q  Median    3Q   Max 
-0.818 -0.776  0.224  0.224  2.224 

Coefficients:

|                | Estimate | Std. Error | t value |  Pr(>|t|) |
|----------------|----------|------------|---------|----------|
| (Intercept)    | 0.8182   | 0.0885     | 9.24    | <2e-16   |
| groupMale      | -0.0419  | 0.1005     | -0.42   | 0.68     |
| groupI choose not to provide this information. | -0.4848 | 0.3505 | -1.38 |

---

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.587 on 196 degrees of freedom  
Multiple R-squared: 0.00973, Adjusted R-squared: -0.000372  
F-statistic: 0.963 on 2 and 196 DF, p-value: 0.383
if_statements_resources_used ~ institution

Figure 75. One-way ANOVA if_statements_resources_used and institution

```r
working_data <- final_Data
response <- working_data[, "if_statements_resources_used"]
group <- factor(working_data[, "institution"])
granovagg.lw(response, group = group)
```

By-group summary statistics for your input data (ordered by group means)
Below is a linear model summary of your input data

Call:
  \texttt{lm(formula = score \sim group, data = owp$data)}

Residuals:
  
  Min 1Q Median 3Q Max
  -1.062 -0.742 0.259 0.259 1.938

Coefficients:

| Group                               | Estimate | Std. Error | t value | Pr(>|t|) |
|-------------------------------------|----------|------------|---------|----------|
| (Intercept)                         | 0.7931   | 0.1086     | 7.30    | 7.1e-12  *** |
| Hudson Valley CC                    | 0.2694   | 0.1822     | 1.48    | 0.14     |
| University at Albany, SUNY          | -0.0516  | 0.1189     | -0.43   | 0.66     |
| University at Potsdam, SUNY         | 0.0640   | 0.2463     | 0.26    | 0.80     |

---

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.585 on 195 degrees of freedom
Multiple R-squared: 0.0226,  Adjusted R-squared: 0.00754
F-statistic: 1.5 on 3 and 195 DF,  p-value: 0.216
if_statements_resources_used ~ previous_online_classes

Figure 76. One-way ANOVA if_statements_resources_used and previous_online_classes
working_data <- final_Data
response <- working_data[, "if_statements_resources_used"]
group <- factor(working_data[, "previous_online_classes"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
<td>1.00</td>
<td>0.22</td>
<td>0.29</td>
<td>0.33</td>
</tr>
<tr>
<td>2</td>
<td>0.78</td>
<td>0.86</td>
<td>0.00</td>
<td>0.19</td>
<td>0.44</td>
</tr>
<tr>
<td>3</td>
<td>0.80</td>
<td>0.84</td>
<td>0.02</td>
<td>0.37</td>
<td>0.61</td>
</tr>
<tr>
<td>4 more than 2</td>
<td>1.00</td>
<td>1.00</td>
<td>0.22</td>
<td>0.29</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
  Min 1Q Median 3Q Max
-1.000 -0.552  0.199  0.199  2.199

Coefficients:

| Estimate | Std. Error | t value | Pr(>|t|) |
|----------|------------|---------|---------|
| (Intercept) | 0.8014 | 0.0481 | 16.65 | <2e-16 *** |
| group1 | -0.2496 | 0.1182 | -2.11 | 0.036 * |
| group2 | -0.0236 | 0.1998 | -0.12 | 0.906 |
| groupmore than 2 | 0.1986 | 0.1577 | 1.26 | 0.209 |

---

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.582 on 195 degrees of freedom
Multiple R-squared: 0.0337, Adjusted R-squared: 0.0189
F-statistic: 2.27 on 3 and 195 DF, p-value: 0.0817
if\_statements\_resources\_used \sim semesters\_in\_college

**Figure 77.** One-way ANOVA if\_statements\_resources\_used and semesters\_in\_college
working_data <- final_Data
response <- working_data[, "if_statements_resources_used"]
group <- factor(working_data[, "semesters_in_college"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th></th>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0.55</td>
<td>0.43</td>
<td>-0.23</td>
<td>0.47</td>
<td>0.69</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.71</td>
<td>0.79</td>
<td>-0.07</td>
<td>0.28</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.83</td>
<td>1.00</td>
<td>0.05</td>
<td>0.15</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.86</td>
<td>0.89</td>
<td>0.08</td>
<td>0.40</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.88</td>
<td>0.85</td>
<td>0.10</td>
<td>0.44</td>
<td>0.66</td>
</tr>
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</table>

group.size
<p>| | |</p>
<table>
<thead>
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<th></th>
<th></th>
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</thead>
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<tr>
<td></td>
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<td></td>
<td>2</td>
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<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
     Min      1Q  Median      3Q     Max
-0.875  -0.709   0.138   0.291  2.138

Coefficients:
             Estimate Std. Error t value Pr(>|t|)  
(Intercept)   0.545      0.177    3.09  0.0023 **
group2       0.164      0.188    0.87  0.3833 
group3       0.288      0.244    1.18  0.2403 
group4       0.330      0.205    1.61  0.1090 
group5       0.317      0.193    1.64  0.1018 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.586 on 194 degrees of freedom
Multiple R-squared: 0.0256,    Adjusted R-squared: 0.00552
F-statistic: 1.27 on 4 and 194 DF,  p-value: 0.281
boolean_algebra_resources_used $\sim$ age

Figure 78. One-way ANOVA boolean_algebra_resources_used and age

Contrast coefficients based on group means
```r
working_data <- final_Data
response <- working_data[, "boolean_algebra_resources_used"]
group <- factor(working_data[, "age"])
granovagg.lw(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>32</td>
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<td>0.00</td>
<td>-0.69</td>
<td>NA</td>
</tr>
<tr>
<td>19</td>
<td>45</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.69</td>
<td>NA</td>
</tr>
<tr>
<td>20</td>
<td>47</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.69</td>
<td>NA</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0.27</td>
<td>0.14</td>
<td>-0.42</td>
<td>0.22</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
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<td>0.34</td>
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<tr>
<td>2</td>
<td>17</td>
<td>0.50</td>
<td>0.50</td>
<td>-0.19</td>
<td>0.50</td>
</tr>
<tr>
<td>7</td>
<td>22</td>
<td>0.50</td>
<td>0.50</td>
<td>-0.19</td>
<td>0.29</td>
</tr>
<tr>
<td>8</td>
<td>23</td>
<td>0.50</td>
<td>0.50</td>
<td>-0.19</td>
<td>0.50</td>
</tr>
<tr>
<td>21</td>
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<td>0.50</td>
<td>0.50</td>
<td>-0.19</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>0.69</td>
<td>0.61</td>
<td>0.00</td>
<td>0.51</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>0.74</td>
<td>0.81</td>
<td>0.04</td>
<td>0.30</td>
</tr>
<tr>
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<td>0.14</td>
<td>0.62</td>
</tr>
<tr>
<td>9</td>
<td>24</td>
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<td>0.75</td>
<td>0.14</td>
<td>0.57</td>
</tr>
<tr>
<td>10</td>
<td>25</td>
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<td>1.00</td>
<td>0.31</td>
<td>NA</td>
</tr>
<tr>
<td>11</td>
<td>26</td>
<td>1.00</td>
<td>1.00</td>
<td>0.31</td>
<td>0.00</td>
</tr>
<tr>
<td>14</td>
<td>30</td>
<td>1.00</td>
<td>1.00</td>
<td>0.31</td>
<td>NA</td>
</tr>
<tr>
<td>15</td>
<td>31</td>
<td>1.00</td>
<td>1.00</td>
<td>0.31</td>
<td>NA</td>
</tr>
<tr>
<td>17</td>
<td>33</td>
<td>1.00</td>
<td>1.00</td>
<td>0.31</td>
<td>NA</td>
</tr>
<tr>
<td>18</td>
<td>44</td>
<td>1.00</td>
<td>1.00</td>
<td>0.31</td>
<td>NA</td>
</tr>
<tr>
<td>12</td>
<td>27</td>
<td>2.50</td>
<td>2.50</td>
<td>1.81</td>
<td>4.50</td>
</tr>
<tr>
<td>13</td>
<td>28</td>
<td>2.50</td>
<td>2.50</td>
<td>1.81</td>
<td>4.50</td>
</tr>
</tbody>
</table>

| group.size | 16 | 19 | 20 | 1 | 11 | 5 | 25 | 2 | 2 | 7 | 8 | 2 | 21 | 2 | 3 | 49 | 4 | 61 | 6 | 18 | 9 | 6 | 10 | 1 | 11 | 3 | 14 | 1 |
```

233
The following groups are likely to be overplotted

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>32</td>
<td>0.00</td>
</tr>
<tr>
<td>19</td>
<td>45</td>
<td>0.00</td>
</tr>
<tr>
<td>20</td>
<td>47</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>0.44</td>
</tr>
<tr>
<td>2</td>
<td>17</td>
<td>0.50</td>
</tr>
<tr>
<td>7</td>
<td>22</td>
<td>0.50</td>
</tr>
<tr>
<td>8</td>
<td>23</td>
<td>0.50</td>
</tr>
<tr>
<td>21</td>
<td>49</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>0.69</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>0.74</td>
</tr>
<tr>
<td>6</td>
<td>21</td>
<td>0.83</td>
</tr>
<tr>
<td>9</td>
<td>24</td>
<td>0.83</td>
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<tr>
<td>10</td>
<td>25</td>
<td>1.00</td>
</tr>
<tr>
<td>11</td>
<td>26</td>
<td>1.00</td>
</tr>
<tr>
<td>14</td>
<td>30</td>
<td>1.00</td>
</tr>
<tr>
<td>15</td>
<td>31</td>
<td>1.00</td>
</tr>
<tr>
<td>17</td>
<td>33</td>
<td>1.00</td>
</tr>
<tr>
<td>18</td>
<td>44</td>
<td>1.00</td>
</tr>
<tr>
<td>12</td>
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<td>2.50</td>
</tr>
<tr>
<td>13</td>
<td>28</td>
<td>2.50</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
lm(formula = score ~ group, data = owp$data)

Residuals:
Min 1Q Median 3Q Max
-1.500 -0.694 0.167 0.306 2.306

Coefficients:

<p>|            | Estimate | Std. Error | t value | Pr(&gt;|t|) |
|------------|----------|------------|---------|---------|
| (Intercept)| 0.273    | 0.200      | 1.36    | 0.175   |
| group17    | 0.227    | 0.510      | 0.45    | 0.656   |
| group18    | 0.421    | 0.221      | 1.90    | 0.059   |
| group19    | 0.465    | 0.217      | 2.14    | 0.034   |
| group20    | 0.167    | 0.240      | 0.70    | 0.487   |</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>Coefficient 1</th>
<th>Coefficient 2</th>
<th>Coefficient 3</th>
<th>Coefficient 4</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>group21</td>
<td>0.561</td>
<td>0.254</td>
<td>2.21</td>
<td>0.029</td>
<td>*</td>
</tr>
<tr>
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<td>0.308</td>
<td>0.74</td>
<td>0.462</td>
<td></td>
</tr>
<tr>
<td>group23</td>
<td>0.227</td>
<td>0.510</td>
<td>0.45</td>
<td>0.656</td>
<td></td>
</tr>
<tr>
<td>group24</td>
<td>0.561</td>
<td>0.337</td>
<td>1.66</td>
<td>0.098</td>
<td>.</td>
</tr>
<tr>
<td>group25</td>
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<td>0.693</td>
<td>1.05</td>
<td>0.295</td>
<td></td>
</tr>
<tr>
<td>group26</td>
<td>0.727</td>
<td>0.432</td>
<td>1.68</td>
<td>0.094</td>
<td>.</td>
</tr>
<tr>
<td>group27</td>
<td>2.227</td>
<td>0.510</td>
<td>4.37</td>
<td>2.1e-05 ***</td>
<td>***</td>
</tr>
<tr>
<td>group28</td>
<td>2.227</td>
<td>0.510</td>
<td>4.37</td>
<td>2.1e-05 ***</td>
<td>***</td>
</tr>
<tr>
<td>group29</td>
<td>0.727</td>
<td>0.693</td>
<td>1.05</td>
<td>0.295</td>
<td></td>
</tr>
<tr>
<td>group30</td>
<td>0.727</td>
<td>0.693</td>
<td>1.05</td>
<td>0.295</td>
<td></td>
</tr>
<tr>
<td>group31</td>
<td>0.727</td>
<td>0.693</td>
<td>1.05</td>
<td>0.295</td>
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</tr>
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<td>-0.39</td>
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<tr>
<td>group33</td>
<td>0.727</td>
<td>0.693</td>
<td>1.05</td>
<td>0.295</td>
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</tr>
<tr>
<td>group34</td>
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<td>0.693</td>
<td>1.05</td>
<td>0.295</td>
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<td>0.693</td>
<td>-0.39</td>
<td>0.694</td>
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</tr>
<tr>
<td>group37</td>
<td>0.227</td>
<td>0.510</td>
<td>0.45</td>
<td>0.656</td>
<td></td>
</tr>
</tbody>
</table>

---

Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.664 on 178 degrees of freedom
Multiple R-squared: 0.203, Adjusted R-squared: 0.113
F-statistic: 2.26 on 20 and 178 DF,  p-value: 0.0255
boolean_algebra_resources_used $\sim$ gender

Figure 79. One-way ANOVA boolean_algebra_resources_used and gender
```r
working_data <- final_Data
response <- working_data[, "boolean_algebra_resources_used"]
group <- factor(working_data[, "gender"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 I choose not to provide this information.</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>2</td>
<td>Male</td>
<td>0.68</td>
</tr>
<tr>
<td>1</td>
<td>Female</td>
<td>0.75</td>
</tr>
</tbody>
</table>

contrast variance standard.deviation group.size
| 3 | -0.36 | 0.33 | 0.58 | 3 |
| 2 | -0.01 | 0.55 | 0.74 | 152 |
| 1 | 0.06 | 0.33 | 0.58 | 44 |

Below is a linear model summary of your input data

Call:
`lm(formula = score ~ group, data = owp\$data)`

Residuals:

<table>
<thead>
<tr>
<th>Min</th>
<th>1Q</th>
<th>Median</th>
<th>3Q</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.750</td>
<td>-0.684</td>
<td>0.250</td>
<td>0.316</td>
<td>3.316</td>
</tr>
</tbody>
</table>

Coefficients:

| Estimate | Std. Error | t value | Pr(>|t|) |
|----------|------------|---------|---------|
| (Intercept) | 0.7500 | 0.1065 | 7.04 |
| groupMale | -0.0658 | 0.1209 | -0.54 |
| groupI choose not to provide this information. | -0.4167 | 0.4214 | -0.99 |

Residual standard error: 0.706 on 196 degrees of freedom
Multiple R-squared: 0.00552, Adjusted R-squared: -0.00463
F-statistic: 0.544 on 2 and 196 DF, p-value: 0.581
```

237
boolean_algebra_resources_used ~ institution

**Figure 80.** One-way ANOVA boolean_algebra_resources_used and institution
working_data <- final_Data
response <- working_data[, "boolean_algebra_resources_used"]
group <- factor(working_data[, "institution"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adirondack CC</td>
<td>0.59</td>
<td>0.63</td>
<td>-0.11</td>
<td>0.25</td>
</tr>
<tr>
<td>University at Albany, SUNY</td>
<td>0.67</td>
<td>0.56</td>
<td>-0.03</td>
<td>0.58</td>
</tr>
<tr>
<td>Hudson Valley CC</td>
<td>1.00</td>
<td>1.00</td>
<td>0.31</td>
<td>0.13</td>
</tr>
<tr>
<td>University at Potsdam, SUNY</td>
<td>1.00</td>
<td>1.00</td>
<td>0.31</td>
<td>0.33</td>
</tr>
</tbody>
</table>

standard.deviation group.size

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.50</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>0.76</td>
<td>147</td>
</tr>
<tr>
<td>2</td>
<td>0.37</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>0.58</td>
<td>7</td>
</tr>
</tbody>
</table>

The following groups are likely to be overplotted

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>contrast</th>
<th>group.size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hudson Valley CC</td>
<td>1.00</td>
<td>0.31</td>
<td>147</td>
</tr>
<tr>
<td>University at Potsdam, SUNY</td>
<td>1.00</td>
<td>0.31</td>
<td>7</td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:

lm(formula = score ~ group, data = owp$data)

Residuals:

    Min     1Q    Median     3Q    Max
-1.000 -0.667  0.000  0.333  3.333

Coefficients:

                          Estimate Std. Error t value Pr(>|t|)
(Intercept)               0.5862     0.1301   4.51  1.1e-05 ***
groupHudson Valley CC     0.4138     0.2182   1.90  0.059     .
groupUniversity at Albany, SUNY 0.0805     0.1423   0.57   0.573
groupUniversity at Potsdam, SUNY 0.4138     0.2950   1.40   0.162
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.701 on 195 degrees of freedom
Multiple R-squared:  0.0265,   Adjusted R-squared:  0.0115
F-statistic: 1.77 on 3 and 195 DF,  p-value: 0.155

239
boolean\_algebra\_resources\_used \sim previous\_online\_classes

**Figure 81.** One-way ANOVA boolean\_algebra\_resources\_used and previous\_online\_classes
```r
working_data <- final_Data
response <- working_data[, "boolean_algebra_resources_used"]
group <- factor(working_data[, "previous_online_classes"])
granovagg.lw(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 more than 2</td>
<td>0.67</td>
<td>0.78</td>
<td>-0.03</td>
<td>0.24</td>
<td>0.49</td>
</tr>
<tr>
<td>1</td>
<td>0.68</td>
<td>0.67</td>
<td>-0.02</td>
<td>0.39</td>
<td>0.62</td>
</tr>
<tr>
<td>2</td>
<td>0.72</td>
<td>0.47</td>
<td>0.03</td>
<td>0.92</td>
<td>0.96</td>
</tr>
<tr>
<td>3</td>
<td>0.89</td>
<td>0.57</td>
<td>0.20</td>
<td>1.61</td>
<td>1.27</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>group.size</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>146</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
   Min     1Q Median     3Q    Max
-0.889 -0.678  0.322  0.322  3.276

Coefficients:             Estimate Std. Error t value Pr(>|t|)
(Intercept)              0.6781     0.0586   11.56  <2e-16 ***
group1                   0.0461     0.1440    0.32     0.75
group2                   0.2108     0.2433    0.87     0.39
groupmore than 2         -0.0114     0.1921   -0.06     0.95
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.709 on 195 degrees of freedom
Multiple R-squared:  0.00424,  Adjusted R-squared: -0.0111
F-statistic: 0.276 on 3 and 195 DF,  p-value: 0.842
```
boolean\_algebra\_resources\_used \sim semesters\_in\_college

**Figure 82.** One-way ANOVA boolean\_algebra\_resources\_used and semesters\_in\_college
working_data <- final_Data
response <- working_data[, "boolean_algebra_resources_used"]
group <- factor(working_data[, "semesters_in_college"])
granovagg.1w(response, group = group)

By-group summary statistics for your input data (ordered by group means)

<table>
<thead>
<tr>
<th>group</th>
<th>group.mean</th>
<th>trimmed.mean</th>
<th>contrast</th>
<th>variance</th>
<th>standard.deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.36</td>
<td>0.29</td>
<td>-0.33</td>
<td>0.25</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>0.42</td>
<td>0.38</td>
<td>-0.28</td>
<td>0.27</td>
<td>0.51</td>
</tr>
<tr>
<td>4</td>
<td>0.56</td>
<td>0.55</td>
<td>-0.13</td>
<td>0.32</td>
<td>0.56</td>
</tr>
<tr>
<td>2</td>
<td>0.74</td>
<td>0.69</td>
<td>0.05</td>
<td>0.47</td>
<td>0.69</td>
</tr>
<tr>
<td>5</td>
<td>0.81</td>
<td>0.75</td>
<td>0.12</td>
<td>0.68</td>
<td>0.83</td>
</tr>
</tbody>
</table>

group.size
| 1     | 11         |
| 3     | 12         |
| 4     | 32         |
| 2     | 86         |
| 5     | 58         |

Below is a linear model summary of your input data

Call:
  lm(formula = score ~ group, data = owp$data)

Residuals:
  Min     1Q Median     3Q    Max
-0.810 -0.744  0.190  0.256  3.190

Coefficients:
    Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.364     0.211   1.73 0.086
group2      0.381     0.224   1.70 0.090
group3      0.053     0.291   0.18 0.856
group4      0.199     0.244   0.81 0.416
group5      0.447     0.230   1.94 0.053
---
Signif. codes:  ?**'***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.698 on 194 degrees of freedom
Multiple R-squared:  0.0374,  Adjusted R-squared:  0.0176
F-statistic: 1.89 on 4 and 194 DF,  p-value: 0.115
Appendix P. R SCRIPTS

01convertResourceFrequencyReportsToDataTables.R

```r
#remove all global variables
rm(list=ls())
#preserve original path
origPath <- getwd()
setwd(path)

require(stringr)

convertResourceFrequencyTabDelimitedReportsToDataTables <- function(filename, path) {
  # Blackboard generates report files in a non-standard Excel format.
  # Those files must first be opened in Excel, then SAVEd AS... to a tab delimited format
  # before being read in by this script.
  #
  # This function then parses those tab-delimited reports into proper data tables.
  #
  # generate a task name from the 1st 3 chars concated with the resource number: BinRes1
  task <- sub("^(...).*\(Res\d\).*\$", "\1\2", filename)
  #open each resource file
  resourceFrequency.raw <- read.delim(paste0(path, filename),
    , skip = 4,
    , nrows = 4000,
    , blank.lines.skip = TRUE,
    , stringsAsFactors = FALSE
  )

  # drop trailing summary report lines
  resourceFrequency.raw <- resourceFrequency.raw[1:546, ]

  names(resourceFrequency.raw)[ which(names(resourceFrequency.raw) == "X2014.01") ] <- "student"

  # extract rows with frequency data
  jan <- resourceFrequency.raw[1:272, ]
  feb <- resourceFrequency.raw[275:546, ]

  #merge the January and February rows
  resourceFrequency <- merge(jan, feb,
    by="student"
  )
}
```

all.x = TRUE
all.y = TRUE

#remove all whitespace from the name for unique identifier
resourceFrequency$student <- str_replace_all(resourceFrequency$student, pattern=" ", repl="")

#names of the columns

#new names of the columns

#concatenate the day and the resource
daysList <- paste0(daysList, ".", task)
#rename columns
names(resourceFrequency) <- c("student", daysList)

# ensure frequency columns are being treated as integer data
for (day in daysList) {
  resourceFrequency[, day] <- as.integer(resourceFrequency[, day])
}

#output file as a -clean file
write.table(resourceFrequency
  , row.names = FALSE
  , sep = "\t"
  , file=paste0(path, "output/", basename(filename), "-clean.txt")
)

#get all of the files that have the date 02/15/14
resourceFrequencyTabDelimitedReports <- list.files(path=path, pattern=".*021514\..txt"", recursive=TRUE)
#apply the function to every element in the folder
lapply(resourceFrequencyTabDelimitedReports, convertResourceFrequencyTabDelimitedReportsToDataTables, path=path)

#set the path back to the original
setwd(origPath)
	  
	  

02mergeFrequencyAndBlackboardData.R	  
#Remove	  global	  variables	  
rm(list=ls())	  
#preserve	  old	  path	  
origPath	  <-­‐	  getwd()	  
setwd(path)	  

	  

#read	  the	  grade	  book	  file	  into	  memory	  
blackBoard_data	  <-­‐	  read.delim("gc_hurd_fullgc_2014-­‐02-­‐15-­‐08-­‐24-­‐00.txt"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  header	  =	  TRUE	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  blank.lines.skip	  =	  TRUE	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  stringsAsFactors	  =	  FALSE	  
)	  
require(stringr)	  
#Need	  to	  create	  the	  student	  column	  that	  combines	  Last.Name,	  First.Name,	  and	  username	  
#student	  column	  is	  needed	  for	  merge	  method	  
blackBoard_data$student	  <-­‐	  paste0(blackBoard_data$Last.Name,	  ',',	  
blackBoard_data$First.Name,	  '	  (',	  blackBoard_data$Username,	  ')'	  )	  
blackBoard_data$student	  <-­‐	  str_replace_all(blackBoard_data$student,	  pattern="	  ",	  
repl="")	  
#	  Select	  only	  those	  columns	  of	  interest	  
#	  
blackBoard_data	  <-­‐	  blackBoard_data[,	  c("student",	  "Student.ID",	  "Last.Access",	  
"Availability"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  "Opening.Survey.instructor.download.column.total..1498939"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  "Agree.to.participate.instructor.download.column.total..1498983"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  "Agree.to.participate.results"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  
"Module.1.Binary.Numbers.pretest.instructor.download.column.total..1603188"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  
"Module.1.Binary.Numbers.posttest.instructor.download.column.total..1603193"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  "Module.1.Exit.Survey.instructor.download.column.total..1588020"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  "Exit.Survey.1.Results"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  
"Module.2.If.Statements.pretest.instructor.download.column.total..1604964"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  
"Module.2.If.Statements.posttest.instructor.download.column.total..1605039"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  "Module.2.Exit.Survey.instructor.download.column.total..1605260"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  "Exit.Survey.2.Results"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  
"Module.3.Boolean.logic.pretest.instructor.download.column.total..1605705"	  
	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  	  ,	  

246	  
	  


What are the preferred column names for working with the data?

cnames <- c("student", "ID", "LDOAccess", "Availability"
  , "OS_survey"
  , "ATP_survey"
  , "ATP_results"
  , "M1BN_pretest", "M1BN_posttest", "M1E_survey", "M1E_results"
  , "M2IF_pretest", "M2IF_posttest", "M2E_survey", "M2E_results"
  , "M3BA_pretest", "M3BA_posttest", "M3E_survey", "M3E_results"
)

stopifnot(length( names(blackBoard_data) ) == length( cnames ))

# Rename the columns to the variable names
names(blackBoard_data) <- c(cnames)

mergeResourceUseFrequencyData <- function(filename, path) {
  # Get all the cleaned data files into R
  # Reorganize the data and create the student field in the grade book file
  # One by one merge the cleaned data files into the grade book file

  dd <- read.delim(paste0(path, filename)
  , header = TRUE
  , blank.lines.skip = TRUE
  , stringsAsFactors = FALSE  )

  blackBoard_data <<- merge(blackBoard_data, dd
  , by="student"
  , all.x = TRUE
  , all.y = TRUE
  )

  return(0)
}

# Cleaned files were generated by the R script 01convertBlackboardReportsToDataFiles.R
cleanedDataFiles <- list.files(path=paste0(path, "output/"), pattern=".*-clean\.[tT]xt$", recursive=TRUE)
lapply(cleanedDataFiles, mergeResourceUseFrequencyData, path=paste0(path, "output/"))

#Extract and create a column using just the lastname, firstname of the student
blackBoard_data$nameOnly <- str_trim(str_extract(blackBoard_data$student, "^.*,[^\[]*\(\]*\))

#Reorder the columns so I can see the nameOnly column
blackBoard_data <- blackBoard_data[,c(410,1:409)]

save(blackBoard_data, file="output/AllBlackboardData.Rdata")

#Write the results to a Text File
write.table(blackBoard_data
    , row.names = FALSE
    , sep = "\t"
    , file = "output/AllBlackboardData.txt"
)

#set the path back to original
setwd(origPath)
# A major issue is that students who had more than one attempt but only complete the Opening Survey in one attempt

# Need to load resource frequency and demographic data

resourceFrequency <- read.delim("output/AllBlackboardData.txt" 
  , header = TRUE 
  , blank.lines.skip = TRUE 
  , stringsAsFactors = FALSE 
)

openingSurvey <- read.delim("Opening Survey.txt" 
  , header = TRUE 
  , blank.lines.skip = TRUE 
  , stringsAsFactors = FALSE 
)

# Remove the Question.ID columns
openingSurvey <- openingSurvey[, -grep("*Question*", colnames(openingSurvey))]

# Rename column headers
openingSurvey <- openingSurvey[, c("Answer.1", 
  "Answer.2", 
  "Answer.3", 
  "Answer.4", 
  "Answer.5", 
  "Answer.6", 
  "Answer.7", 
  "Answer.8", 
  "Answer.9", 
  "Answer.10", 
  "Answer.11", 
  "Answer.12"
# What are the preferred column names for working with the data?
cnames <- c("Q1_FN_Answer",  
            "Q2_LN_Answer",  
            "Q3_ID_Answer",  
            "Q4_College_Answer",  
            "Q5_ClassEnrolled_Answer",  
            "Q6_Section_Answer",  
            "Q7_Professor_Answer",  
            "Q8_Gender_Answer",  
            "Q9_Age_Answer",  
            "Q10_OnlineClasses_Answer",  
            "Q11_Interest_Answer",  
            "Q12_NumberSemester_Answer"
)

stopifnot(length( names(openingSurvey) ) == length( cnames ))

# Rename the columns to the variable names
names(openingSurvey) <- c(cnames)

# Copy duplicate students agree to participate
resourceFrequency[50, c('ATP_results')]<- resourceFrequency[49, c('ATP_results')]

# All rows identified for removal, also any rows that have changed and old data can be removed.
resourceFrequency <- resourceFrequency[-c(1, 12, 33, 49, 52, 63, 65, 70, 82, 84, 91, 102, 108, 150, 181, 193, 232, 241, 242, 243),]

# Copy Student ID from 40 to 42 and delete 40
openingSurvey[42, c('Q3_ID_Answer')] <- openingSurvey[40, c('Q3_ID_Answer')]

# Now it is safe to remove 40
openingSurvey$Q1_FN_Answer <- str_replace_all(openingSurvey$Q1_FN_Answer, pattern=" ", repl="")
openingSurvey$Q2_LN_Answer <- str_replace_all(openingSurvey$Q2_LN_Answer, pattern=" ", repl="")

# Now that data has been fixed removed the rows that are not needed.
openingSurvey <- openingSurvey[-c(1, 3, 4, 10, 40, 102, 143),]

# Write the results to a Text File
write.table(resourceFrequency, row.names = FALSE, sep = "\t", file = "output/AllBlackboardData.txt")

# Write the results to a Text File
write.table(openingSurvey)
, row.names = FALSE
, sep = "\t"
, file = "output/OpeningSurvey.txt"
)

setwd(origPath)
#remove all global variables
rm(list=ls())
#preserve original path
origPath <- getwd()
setwd(path)

blackBoard_data <- read.delim("output/AllBlackboardData.txt"
    , header = TRUE
    , blank.lines.skip = TRUE
    , stringsAsFactors = FALSE
)

openingSurvey_data <- read.delim("output/OpeningSurvey.txt"
    , header = TRUE
    , blank.lines.skip = TRUE
    , stringsAsFactors = FALSE
)

require(stringr)

#Need to create the student column that combines Last.Name, First.Name, and username
#student column is needed for merge method
openingSurvey_data$nameOnly <- tolower(paste0(
    str_trim(openingSurvey_data$Q2_LN_Answer), ',',
    str_trim(openingSurvey_data$Q1_FN_Answer)))

openingSurvey_data$nameOnly <- tolower(openingSurvey_data$nameOnly)
blackBoard_data$nameOnly <- tolower(blackBoard_data$nameOnly)

openingSurvey_data$nameOnly <- str_trim(str_extract(openingSurvey_data$nameOnly,
    "^.*,[^\(\]\])*\)

# Merge the two files that have been loaded
# Pre-condition: blackBoard_data should be the data-frame that has all the demographic data and all of the data from BB statistic reports
# After this merge the data needs to be inspected to confirm that students didn't use nicknames i.e Thomas -> tom
openingSurvey_data <- merge(openingSurvey_data, blackBoard_data
    , by="nameOnly"
    , all.x = TRUE
    , all.y = TRUE
)
# Remove the learners who did completed the Opening Survey and logged in but didn't answer any of the Learning Module activities
openingSurvey_data <- openingSurvey_data[-c(13, 15, 30, 34, 40, 100, 120, 151, 155, 157, 212, 229, 250, 251),]

# Write the results to a Text File
write.table(openingSurvey_data,
            , row.names = FALSE
            , sep = "\t"
            , file = "output/OpeningSurvey_final.txt"
)

setwd(origPath)
05RemoveNAandBadDatafromBlackboardData.R

#remove global variables
rm(list=ls())
require(stringr)
#preserve original path
origPath <- getwd()
setwd(path)

# Open the file that has all the data merged
Final_openingSurvey_data <- read.delim("output/OpeningSurvey_final.txt"
, header = TRUE
, blank.lines.skip = TRUE
, stringsAsFactors = FALSE
)

#Remove unneeded column
#22:26 ID, Last date of access, Availability, Opening_Survey taken, Agree to Participate taken survey (Results are in another column)
# 30, 34, 38 End of unit survey taken variables
Final_openingSurvey_data <- Final_openingSurvey_data[,-c(15:19, 23, 27, 31)]

#remove all rows that have NAs in assessment scores, Who didn’t answer yes to agree to participate and who did not answer institution or gender
Final_openingSurvey_data <- subset(Final_openingSurvey_data, (ATP_results == "Yes"))
Final_openingSurvey_data <- subset(Final_openingSurvey_data, !(Q4_College_Answer == "<Unanswered>")
Final_openingSurvey_data <- subset(Final_openingSurvey_data, !(Q8_Gender_Answer == "<Unanswered>")
Final_openingSurvey_data <- subset(Final_openingSurvey_data, !is.na(M1BN_pretest))
Final_openingSurvey_data <- subset(Final_openingSurvey_data, !is.na(M1BN_posttest))
Final_openingSurvey_data <- subset(Final_openingSurvey_data, !is.na(M2IF_pretest))
Final_openingSurvey_data <- subset(Final_openingSurvey_data, !is.na(M2IF_posttest))
Final_openingSurvey_data <- subset(Final_openingSurvey_data, !is.na(M3BA_pretest))
Final_openingSurvey_data <- subset(Final_openingSurvey_data, !is.na(M3BA_posttest))

# Write the results to a Text File
write.table(Final_openingSurvey_data
, row.names = FALSE
, sep = "\t"
, file = "output/AllBlackboardData_finaldata.txt"
save(Final_openingSurvey_data, file="output/AllBlackboardData.Rdata")

setwd(origPath)

### 06analysis.R

# remove global variables
rm(list=ls())
# preserve original path
origPath <- getwd()
setwd(path)

require(reshape2)

final_Data <- read.delim("AllBlackboardData_finaldata.txt"
  , header = TRUE
  , blank.lines.skip = TRUE
  , stringsAsFactors = FALSE
)

# Generate the Growth variables
final_Data$M1_Growth <- final_Data$M1BN_posttest - final_Data$M1BN_pretest
final_Data$M2_Growth <- final_Data$M2IF_posttest - final_Data$M2IF_pretest
final_Data$M3_Growth <- final_Data$M3BA_posttest - final_Data$M3BA_pretest

# Total each resource columns to see if the resource was used and how many times PER learner
# Binary numbers go from column 25 to 154
final_Data$binary_number_resources_used <- rowSums(cbind(final_Data[, 25:50]))

# Total each resource columns to see if the resource was used and how many times PER learner
# Boolean Algebra go from 155 to 284
final_Data$boolean_algebra_resources_used <- rowSums(cbind(final_Data[, 155:180]))

# Total each resource columns to see if the resource was used and how many times PER learner
# If statements go from 285 to 414
final_Data$if_statements_resources_used <- rowSums(cbind(final_Data[, 285:310]))

# Remove all the columns for the resources
final_Data <- final_Data[, -c(25:414)]

# rename columns to descriptive variable names
names(final_Data) <- c("nameOnly", "Q1_FN_Answer", "Q2_LN_Answer",
  "Q3_ID_Answer", "institution", "course",
  "section", "professor", "gender",...
"age", "previous_online_classes", "interested_in_study",
"semesters_in_college", "student", "ATP_results",
"module1_binary_numbers_pretest",
  "module1_binary_numbers_posttest",
"external_resources_used_during_module1", "module2_if_statements_pretest",
"module2_if_statements_posttest",
  "external_resources_used_during_module2",
"module3_boolean_algebra_pretest", "module3_boolean_algebra_posttest",
"external_resources_used_during_module3",
  "module1_growth", "module2_growth", "module3_growth",
  "binary_numbers_resources_used",
"boolean_algebra_resources_used", "if_statements_resources_used"
)
#	Write	the	results
to	a	Text	File
write.table(final_Data
  , row.names = FALSE
  , sep = "\t"
  , file = "AllBlackboardData_finaldata2.txt"
)

finalDD.molten <- melt(final_Data, id.vars="student")

setwd(origPath)
Exploratory Data Analyses (EDA) for Andy Hurd’s Dissertation Dataset
=====================================================================

These are examples of the kinds of exploration that may prove useful.

```{r}
load_data, echo=FALSE}
rm(list=ls())
```

Use human-readable parameter names so that output from plots, &c. are usable.

Factors are very useful in R, especially with good column names... Let factors be factors...
```
```
`r recode_as_factors}
final_Data$institution <- as.factor(final_Data$institution)
final_Data$gender <- as.factor(final_Data$gender)
final_Data$previous_online_classes <- as.factor(final_Data$previous_online_classes)
final_Data$interested_in_study <- as.factor(final_Data$interested_in_study)
final_Data$semesters_in_college <- as.factor(final_Data$semesters_in_college)
```

final_Data$external_resources_used_during_module1 <-
  as.factor(final_Data$external_resources_used_during_module1)
final_Data$external_resources_used_during_module2 <-
  as.factor(final_Data$external_resources_used_during_module2)
final_Data$external_resources_used_during_module3 <-
  as.factor(final_Data$external_resources_used_during_module3)
final_Data$gender <- factor(final_Data$gender, levels(final_Data$gender)[c(1, 3, 2)])

...  

Attach the data frame to allow for easy reference. Be sure not to make any changes to final_Data after this point, since you'd be editing a different namespace.

```r, echo=FALSE}
attach(final_Data)
```  

```r
pre_post_comparison}

# Q1
colSums(final_Data[, 28:30])/199

# Q2
lm1 <- lm(module1_binary_numbers_pretest~binary_numbers_resources_used)
plot(module1_binary_numbers_pretest, binary_numbers_resources_used)
abline(lm1)
summary(lm1)

lm2 <- lm(module2_if_statements_pretest~if_statements_resources_used)
plot(module2_if_statements_pretest, if_statements_resources_used)
abline(lm2)
summary(lm2)

lm3 <- lm(module3_boolean_algebra_pretest~boolean_algebra_resources_used)
plot(module3_boolean_algebra_pretest, boolean_algebra_resources_used)
abline(lm3)
summary(lm3)

...  

Crosstab of each of the resources used and predictor variables  
```r cross_qplots}
require(ggplot2)
require(descr)

crosstab(binary_numbers_resources_used, gender, prop.r=TRUE, prop.c=TRUE)
crosstab(age, binary_numbers_resources_used)
crosstab(binary_numbers_resources_used, institution, prop.r=TRUE, prop.c=TRUE)
crosstab(binary_numbers_resources_used, previous_online_classes, prop.r=TRUE, prop.c=TRUE)
crosstab(binary_numbers_resources_used, semesters_in_college, prop.r=TRUE, prop.c=TRUE)
crosstab(if_statements_resources_used, gender, prop.r=TRUE, prop.c=TRUE)
crosstab(age, if_statements_resources_used)
crosstab(if_statements_resources_used, institution, prop.r=TRUE, prop.c=TRUE)
crosstab(if_statements_resources_used, previous_online_classes, prop.r=TRUE, prop.c=TRUE)
crosstab(if_statements_resources_used, semesters_in_college, prop.r=TRUE, prop.c=TRUE)
crosstab(boolean_algebra_resources_used, gender, prop.r=TRUE, prop.c=TRUE)
crosstab(age, boolean_algebra_resources_used)
crosstab(boolean_algebra_resources_used, institution, prop.r=TRUE, prop.c=TRUE)
crosstab(boolean_algebra_resources_used, previous_online_classes, prop.r=TRUE, prop.c=TRUE)
crosstab(boolean_algebra_resources_used, semesters_in_college, prop.r=TRUE, prop.c=TRUE)

qplot(module1_binary_numbers_pretest, module1_binary_numbers_posttest, alpha=0.0005, facets=institution ~ gender, color=age) + stat_smooth(method="lm",se=TRUE)
qplot(module2_if_statements_pretest, module2_if_statements_posttest, alpha=0.0005, facets=institution ~ gender, color=age) + stat_smooth(method="lm",se=TRUE)
qplot(module3_boolean_algebra_pretest, module3_boolean_algebra_posttest, alpha=0.0005, facets=institution ~ gender, color=age) + stat_smooth(method="lm",se=TRUE)
qplot(module1_growth, binary_numbers_resources_used, alpha=0.0005, facets=institution ~ gender, color=age) + stat_smooth(method="lm",se=TRUE)
qplot(module2_growth, if_statements_resources_used, alpha=0.0005, facets=institution ~ gender, color=age) + stat_smooth(method="lm",se=TRUE)
qplot(module3_growth, boolean_algebra_resources_used, alpha=0.0005, facets=institution ~ gender, color=age) + stat_smooth(method="lm",se=TRUE)

... 

Inspect the parameters.

* Do the numeric ranges make sense?
* Do the frequency counts for factors make sense?
* Are there any unexpected levels in the factors?
* Are there any parameters that should be factors that I missed?
Check for correlations and variances
```
#RESEARCH QUESTION NUMBER 1
#What is the mean number of modes of instruction selected per module?

ff <- cbind(binary_numbers_resources_used, if_statements_resources_used, boolean_algebra_resources_used )
colMeans(ff, na.rm = FALSE, dims = 1)

var(boolean_algebra_resources_used)
var(if_statements_resources_used)
var(binary_numbers_resources_used)

#What is the variance in the Growth?
var(module1_growth)
var(module2_growth)
var(module3_growth)

#Is there any correlation between the growth in the modules
cor.test(module1_growth, module2_growth)
cor.test(module1_growth, module3_growth)
cor.test(module2_growth, module3_growth)

#RESEARCH QUESTION NUMBER 2
#Do pretest x <-s correlate with the number of modes of instruction selected by students?

cor.test(module1_binary_numbers_pretest, binary_numbers_resources_used)
cor.test(module2_if_statements_pretest, if_statements_resources_used)
cor.test(module3_boolean_algebra_pretest, boolean_algebra_resources_used)

#RESEARCH QUESTION NUMBER 3
#Does the number of modes of instruction selected correlate with an increase in posttest scores?
cor.test(module1_growth, binary_numbers_resources_used)
cor.test(module2_growth, if_statements_resources_used)
cor.test(module3_growth, boolean_algebra_resources_used)
# RESEARCH QUESTION NUMBER 4
# Is gender correlated with the number of modes of instruction selected?

```r
cor.test(as.numeric(gender), binary_numbers_resources_used)
cor.test(as.numeric(gender), if_statements_resources_used)
cor.test(as.numeric(gender), boolean_algebra_resources_used)
```

# RESEARCH QUESTION NUMBER 5
# Is age correlated with the number of modes of instruction selected?

```r
cor.test(age, binary_numbers_resources_used)
cor.test(age, if_statements_resources_used)
cor.test(age, boolean_algebra_resources_used)
```

# RESEARCH QUESTION NUMBER 6
# Is previous online class experience correlated with the number of modes of instruction selected?

```r
cor.test(as.numeric(previous_online_classes), binary_numbers_resources_used)
cor.test(as.numeric(previous_online_classes), if_statements_resources_used)
cor.test(as.numeric(previous_online_classes), boolean_algebra_resources_used)
```

# RESEARCH QUESTION NUMBER 7
# Does institution type correlate with the number of modes of instruction selected?

```r
cor.test(as.numeric(institution), binary_numbers_resources_used)
cor.test(as.numeric(institution), if_statements_resources_used)
cor.test(as.numeric(institution), boolean_algebra_resources_used)
```

# RESEARCH QUESTION NUMBER 8
# Does the number of college semesters completed correlate with the number of modes of instruction selected?

```r
cor.test(as.numeric(semesters_in_college), binary_numbers_resources_used)
cor.test(as.numeric(semesters_in_college), if_statements_resources_used)
cor.test(as.numeric(semesters_in_college), boolean_algebra_resources_used)
```

...
par(mfrow=c(3,1))
hist(binary_numbers_resources_used, xlim=c(0, 7), ylim=c(0, 200), main="Number of Times any Resource was Accessed")
hist(if_statements_resources_used, xlim=c(0, 7), ylim=c(0, 200), main="")
hist(boolean_algebra_resources_used, xlim=c(0, 7), ylim=c(0, 200), main="")

```
```
Histograms of the Exit Survey
```
```{r hist_exit_survey}
par(mfrow=c(3,1))
plot(external_resources_used_during_module1, xlim=c(0, 5), ylim=c(0, 200),
main="Participants who used outside resources")
plot(external_resources_used_during_module2, xlim=c(0, 5), ylim=c(0, 200), main="")
plot(external_resources_used_during_module3, xlim=c(0, 5), ylim=c(0, 200), main="")
par(mfrow=c(1,1))
```
```{r}
Qplot of Gender and outside resources used
```
```{r qplots_gender_outside_resources_used}
require(ggplot2)
qplot(binary_numbers_resources_used, external_resources_used_during_module1, alpha=0.005, facets=institution~gender, size=20)
qplot(if_statements_resources_used, external_resources_used_during_module2, alpha=0.005, facets=institution~gender, size=20)
qplot(boolean_algebra_resources_used, external_resources_used_during_module3, alpha=0.005, facets=institution~gender, size=20)
```
```{r}
Compare the variance of gender and resources
```
```{r F_test_variance}
var.test(gender, binary_numbers_resources_used)
var.test(gender, if_statements_resources_used)
var.test(gender, boolean_algebra_resources_used)
```
Compare the variance of age and resources
```
{r F_test_variance_age}
```

```{r}
var.test(age, binary_numbers_resources_used)
var.test(age, if_statements_resources_used)
var.test(age, boolean_algebra_resources_used)
``` ...

What percentage of total respondents by school were females/males/other?
```
{r cross_tabulations}
```
```{r}
require(descr) #crosstab
require(xtable)

myTable <- crosstab(institution, gender
                    , prop.r=TRUE, prop.c=TRUE, prop.t=FALSE
                    , prop.chisq=FALSE, chisq=FALSE
)

myTable
``` ...
```
{r results='asis'}
```
print(xtable(myTable), type='html')
``` ...

What percentage of total respondents by age were females/males/other?
```
{r cross_tabulations_age}
```
```{r}
require(descr) #crosstab
require(xtable)

myTable <- crosstab(age, gender
                     , prop.r=TRUE, prop.c=TRUE, prop.t=FALSE
                     , prop.chisq=FALSE, chisq=FALSE
                     )

myTable
``` ...

What percentage of total respondents by age experienced more online classes?
```
{r cross_tabulations_OnlineClass}
```
```{r}
require(descr) #crosstab
require(xtable)
```
myTable <- crosstab(age, previous_online_classes
  , prop.r=TRUE, prop.c=TRUE, prop.t=FALSE
  , prop.chisq=FALSE, chisq=FALSE
)

myTable
```
```

What percentage of total respondents by gender and who completed semesters in college
```
```{r cross_tabulations_Semesters}
require(descr) #crosstab
require(xtable)

myTable <- crosstab(gender, semesters_in_college
  , prop.r=TRUE, prop.c=TRUE, prop.t=FALSE
  , prop.chisq=FALSE, chisq=FALSE
)

myTable
```
```

```
```

What are the distributions of individual parameters?
GranovaGG by growth
```
```{r 1d_inspect_distribution_of_individual_parameters}
require(ggplot2)
require(granovaGG)

qplot(institution)
hist(age)

#Module 1 Growth ANOVA
qplot(module1_growth)

working_data <- final_Data
response <- working_data[, "module1_growth"]
group <- factor(working_data[, "age"])
granovagg.1w(response, group=group)

working_data <- final_Data #subset(final_Data, gender == "Male" | gender == "Female")
response <- working_data[, "module1_growth"]
group <- factor(working_data[, "gender"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "module1_growth"]
group <- factor(working_data[, "institution"])
```
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "module1_growth"]
group <- factor(working_data[, "previous_online_classes"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "module1_growth"]
group <- factor(working_data[, "semesters_in_college"])
granovagg.1w(response, group=group)

#Module 2 Growth ANOVA
qplot(module2_growth)

working_data <- final_Data
response <- working_data[, "module2_growth"]
group <- factor(working_data[, "age"])
granovagg.1w(response, group=group)

working_data <- final_Data #subset(final_Data, gender == "Male" | gender == "Female")
response <- working_data[, "module2_growth"]
group <- factor(working_data[, "gender"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "module2_growth"]
group <- factor(working_data[, "institution"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "module2_growth"]
group <- factor(working_data[, "previous_online_classes"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "module2_growth"]
group <- factor(working_data[, "semesters_in_college"])
granovagg.1w(response, group=group)

#Module 3 Growth ANOVA
qplot(module3_growth)

working_data <- final_Data
response <- working_data[, "module3_growth"]
group <- factor(working_data[, "age"])
granovagg.1w(response, group=group)

working_data <- final_Data #subset(final_Data, gender == "Male" | gender == "Female")
response <- working_data[, "module3_growth"]
```
```
```
```r
```
# If Statements resources used ANOVA
working_data <- final_Data
response <- working_data[, "if_statements_resources_used"]
group <- factor(working_data[, "age"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "if_statements_resources_used"]
group <- factor(working_data[, "gender"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "if_statements_resources_used"]
group <- factor(working_data[, "institution"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "if_statements_resources_used"]
group <- factor(working_data[, "previous_online_classes"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "if_statements_resources_used"]
group <- factor(working_data[, "semesters_in_college"])
granovagg.1w(response, group=group)

# Boolean algebra resources used ANOVA
working_data <- final_Data
response <- working_data[, "boolean_algebra_resources_used"]
group <- factor(working_data[, "age"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "boolean_algebra_resources_used"]
group <- factor(working_data[, "gender"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "boolean_algebra_resources_used"]
group <- factor(working_data[, "institution"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "boolean_algebra_resources_used"]
group <- factor(working_data[, "previous_online_classes"])
granovagg.1w(response, group=group)

working_data <- final_Data
response <- working_data[, "boolean_algebra_resources_used"]
group <- factor(working_data[, "semesters_in_college"])
granovagg.1w(response, group=group)
Now let's check to see if the dependant sample plot explains any information
```r
dependSample_module1 <- cbind(post = c(module1_binary_numbers_posttest),
  pre=c(module1_binary_numbers_pretest))
granovagg.ds(dependSample_module1)

dependSample_module2 <- cbind(post = c(module2_if_statements_posttest),
  pre=c(module2_if_statements_pretest))
granovagg.ds(dependSample_module2)

dependSample_module3 <- cbind(post = c(module3_boolean_algebra_posttest),
  pre=c(module3_boolean_algebra_pretest))
granovagg.ds(dependSample_module3)
```

Display a 3d model of the growth of the module. Use a linear model to show the change from Module 1 as it described by Module 2 and 3
```r
require(scatterplot3d)
fit <- lm(module1_growth ~ module2_growth + module3_growth)
s3d <- scatterplot3d(module1_growth, module2_growth, module3_growth, pch = 16,
  highlight.3d = TRUE, type = "h", main = "Comparison of growth within modules",
  xlab = "Module 1", ylab ="Module 2", zlab ="Module 3", box = FALSE)

s3d$plane3d(fit)
```

Display a 3d model of the growth of the module. Use a linear model to show the change from Module 2 as it described by Module 1 and 3
```r
require(scatterplot3d)
fit <- lm(module2_growth ~ module1_growth + module3_growth)
s3d <- scatterplot3d(module1_growth, module2_growth, module3_growth, pch = 16,
  highlight.3d = TRUE, type = "h", main = "Comparison of growth within modules",
  xlab = "Module 1", ylab ="Module 2", zlab ="Module 3", box = FALSE)

s3d$plane3d(fit)
```
highlight.3d = TRUE, type = "h", main = "Comparison of growth within modules", xlab = "Module 1", ylab = "Module 2", zlab = "Module 3", box = FALSE)

s3d$plane3d(fit)

```
Display a 3d model of the growth of the module. Use a linear model to show the change from Module 3 as it described by Module 1 and 2
```

```r
ScatterPlot3d_Growth3
```
require(scatterplot3d)
fit <- lm(module3_growth ~ module1_growth + module2_growth)
s3d <- scatterplot3d(module1_growth, module2_growth, module3_growth, pch = 16, highlight.3d = TRUE, type = "h", main = "Comparison of growth within modules", xlab = "Module 1", ylab = "Module 2", zlab = "Module 3", box = FALSE)

s3d$plane3d(fit)

```
```

Linear regression for Binary numbers
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```
summary(ddlm)
plot(ddlm)
...

Linear regression for If statements

```r
linear_regression_IF
```

```r
ddlm <- lm(if_statements_resources_used ~ institution
           + gender
           + age
           + previous_online_classes
           + interested_in_study
           + semesters_in_college
           + module2_if_statements_pretest
           + module2_if_statements_posttest
           + external_resources_used_during_module2
          )
```

summary(ddlm)
plot(ddlm)
...

Linear regression for If statements modified

```r
linear_regression_IF_modified
```

```r
ddlm <- lm(if_statements_resources_used ~ previous_online_classes
          + module2_if_statements_posttest
         )
```

summary(ddlm)
plot(ddlm)
...

Linear regression for Boolean Algebra

```r
linear_regression_BA
```
ddlm <- lm(boolean_algebra_resources_used ~ institution + gender + age + previous_online_classes + interested_in_study + semesters_in_college + module3_boolean_algebra_pretest + module3_boolean_algebra_posttest + external_resources_used_during_module3)

summary(ddlm)

plot(ddlm)

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Linear regression for Boolean Algebra Modified
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```
summary(ddlm)
plot(ddlm)

```{r linear_regression_module2_growth}

ddlm <- lm(module2_growth ~ institution + gender + age + previous_online_classes + interested_in_study + semesters_in_college + module2_if_statements_pretest + module2_if_statements_posttest + external_resources_used_during_module2 + if_statements_resources_used)

summary(ddlm)
plot(ddlm)

```

Linear regression for Module 3 growth

```{r linear_regression_module3_growth}

ddlm <- lm(module3_growth ~ institution + gender + age + previous_online_classes + interested_in_study + semesters_in_college + module3_boolean_algebra_pretest + module3_boolean_algebra_posttest + external_resources_used_during_module3}

```

...
summary(ddlm)

plot(ddlm)

... 

What's the distribution of given parameters by gender? (what other "by..." make sense to consider?)

```r
2d_inspect_distribution_of_individual_parameters, fig.width=10
```

require(vcd) #mosaicplot

mosaicplot(institution ~ gender
  , main="Institution by Gender"
  , shade=FALSE, color=TRUE
  , xlab="Institution", ylab="Gender")

mosaicplot(age ~ gender
  , main="Age by Gender"
  , shade=FALSE, color=TRUE
  , xlab="Age", ylab="Gender")

plot(institution, module1_growth
  , main="M1 Growth by Institution"
  , xlab="Institution", ylab="Growth")

plot(institution, module2_growth
  , main="M2 Growth by Institution"
  , xlab="Institution", ylab="Growth")

plot(institution, module3_growth
  , main="M3 Growth by Institution"
  , xlab="Institution", ylab="Growth")
...

Pairs plots can be very useful to spot interesting or unexpected interactions among parameters. Because of the large size of pairs plots, viewing on-screen in FULL SCREEN mode is helpful, particularly when you have a very large and hi-res display.

```r
enhanced_pairs_scatterplots
```

factors <- which( sapply(final_Data, FUN=is.factor) )
numerics <- which ( sapply(final_Data, FUN=is.numeric) )

273
working_data <- final_Data[, c( factors, numerics )]

panel.hist <- function(x, ...) {
  usr <- par("usr"); on.exit(par(usr))
  par(usr = c(usr[1:2], 0, 1.5))
  h <- hist(x, plot = FALSE)
  breaks <- h$breaks; nB <- length(breaks)
  y <- h$counts; y <- y/max(y)
  rect(breaks[-nB], 0, breaks[-1], y, col = "cyan", ...)
}

panel.cor <- function(x, y, digits = 2, prefix = "", cex.cor, ...)
{
  usr <- par("usr"); on.exit(par(usr))
  par(usr = c(0, 1, 0, 1))
  r <- abs(cor(x, y))
  txt <- format(c(r, 0.123456789), digits = digits)[1]
  txt <- paste0(prefix, txt)
  if(missing(cex.cor)) cex.cor <- 0.8/strwidth(txt)
  text(0.5, 0.5, txt, cex = cex.cor * r)
}

pairs(final_Data[, factors], diag.panel = panel.hist, lower.panel = panel.cor,
upper.panel = panel.smooth)

```{r large_pairs_plot, fig.width=70, fig.height=70}

names(working_data)
pairs(working_data, diag.panel = panel.hist, lower.panel = panel.cor, upper.panel = panel.smooth)
```

Don't get excited by the numbers, which represent cor() values... some will auto-correlate (1.0) due to the way they were computed. Visually smaller numbers have lower cor() values; visually larger numbers have higher cor() values.

Interesting features to look for:

* regression lines (red) that are anything other than flat horizontal
* strong correlation numbers < 1.0
  * are there unexpected correlations that might indicate that two parameters are dependent upon each other?
* columns/rows with NA data: why? is it appropriate?
NB: the histograms are in the same order as the names() list.

```
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```
m1.part <- rpart(module1_growth ~ institution
  + gender
  + age
  + previous_online_classes
  + interested_in_study
  + semesters_in_college
  + external_resources_used_during_module1
  + binary_numbers_resources_used
 )

print(m1.part)
plot(m1.part)
text(m1.part, use.n = TRUE)

m2.part <- rpart(module2_growth ~ institution
  + gender
  + age
  + previous_online_classes
  + interested_in_study
  + semesters_in_college
  + external_resources_used_during_module2
  + if_statements_resources_used
 )

print(m2.part)
plot(m2.part)
text(m2.part, use.n = TRUE)

m3.part <- rpart(module3_growth ~ institution
  + gender
  + age
  + previous_online_classes
  + interested_in_study
  + semesters_in_college
  + external_resources_used_during_module3
  + boolean_algebra_resources_used
 )

print(m3.part)
plot(m3.part)
text(m3.part, use.n = TRUE)
```

Recursive Partition tree of binary number resources used

276
```r
{r recursive_comparison}

m1.part <- rpart(binary_numbers_resources_used ~ institution
  + gender
  + age
  + previous_online_classes
  + interested_in_study
  + semesters_in_college
  + module1_binary_numbers_pretest
  + module1_binary_numbers_posttest
  + external_resources_used_during_module1
}
print(m1.part)
plot(m1.part)
text(m1.part, use.n = TRUE)
...

Recursive Partition tree of if statement resources used

```r
{r recursive_if_statements}

m2.part <- rpart(if_statements_resources_used ~ institution
  + gender
  + age
  + previous_online_classes
  + interested_in_study
  + semesters_in_college
  + module2_if_statements_pretest
  + module2_if_statements_posttest
  + external_resources_used_during_module2
}
print(m2.part)
plot(m2.part)
text(m2.part, use.n = TRUE)
...

Recursive Partition tree of boolean algebra resources used

```r
{r recursive_boolean_algebra}

m3.part <- rpart(boolean_algebra_resources_used ~ institution
  + gender
  + age
  + previous_online_classes
  + interested_in_study
  + semesters_in_college
```
```{r, echo=FALSE}
print(m3.part)
plot(m3.part)
text(m3.part, use.n = TRUE)
```

```
\```