Spreadsheets Across the Curriculum, 4: Evidence of Student Learning and Attitudes about Spreadsheets in a Physical Geology Course

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Abstract

Spreadsheets have been used in education for teaching math concepts for years. However, when faculty at the University of South Florida began using a new set of spreadsheet-based modules to help teach students math and geology concepts the students were not receptive. The complaint most often heard was that students spent more time learning how to use Excel than they did learning the concepts presented in the modules. We began to wonder if the learning curve for Excel was so great that it prevented our students from attaining the level of learning for the math and geology concepts that we had hoped for. Was Excel getting in the way? To investigate this question, we divided the students in two Introductory Physical Geology courses into two groups: one group was given a set of modules which instructed them to use Excel for all calculations; the other group was simply told to complete the calculations but was not instructed what method to use. We anticipated that students in the Non-Excel group would be less frustrated with the modules and thus their learning of the math and geology concepts presented in the modules would be deeper. However, it turned out that this was incorrect. The results of our study show that whether or not the students used Excel had very little to do with the level of learning they achieved. Despite the complaints by students that Excel was hindering their learning with the modules, students in the study attained high gains for both the math and geology concepts presented in the modules whether they used Excel or not. In fact, the only difference in learning we saw was based on which course the student belonged to. Students in the course led by the author of the modules had much larger gains in knowledge across the board than those in the course led by another instructor. It appears that the spreadsheet-based modules are a useful tool for teaching math and geology concepts to students but that the largest effect on the success of these modules lies in the teaching style and/or proximity to the author of the modules.

Keywords

SSAC, math avoidance, spreadsheets, geoscience education

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Cover Page Footnote

Heather Lehto is a PhD candidate in the Department of Geology at the University of South Florida. She is completing her dissertation on volcano sismology. This study is a chapter of her dissertation fulfilling an option for interested PhD candidates to include a research component in geoscience education.

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Introduction and Motivation

Spreadsheets have become useful tools for teaching math concepts to students as it is believed that they engage the students better and build skills for their future (Ganter and Barker, 2004). It was with this in mind that the Spreadsheets Across the Curriculum (SSAC) program was started as a means of increasing the quantitative literacy and spreadsheet skills of students both at the pilot school (the University of South Florida, USF) and beyond (Vacher and Lardner, 2010, 2011). The SSAC program entailed the creation and implementation of Excel spreadsheet-based modules that guide the student through a math problem based in some disciplinary context. At USF, modules were first implemented in an upper-division geology course for majors in 2005 (McGee, 2010). The module concept quickly spread throughout the USF geology faculty, and modules were soon included in several courses at USF (e.g., Volcanology, Introduction to Seismology, Geology of the National Parks).

As geology majors at USF used the modules in their courses, a negative view began to emerge amongst the students. According to that view, the modules were too difficult because of the steep learning curve associated with using the spreadsheets. The sharp learning curve for the use of Excel was also evident in a study by Wetzel (2011) in which student volunteers were paid to complete SSAC modules, pre- and post-module tests, and exit interviews for ten modules. Wetzel (2011) concluded that instructors should start off with a very simple module and then add more-difficult modules as the semester progressed so that students had a chance to slowly build up their Excel skills.

Based on the study by Wetzel (2011) and the rumblings from our students we began to wonder if the spreadsheet itself was getting in the way of the students’ learning. Our primary goal as geoscience educators is to teach our students about the Earth they live on, and much of geology requires understanding and applying math (which, these days, should not be a surprise to students). A secondary goal is to give our students skills they will need in the future (e.g., Excel skills). Were our modules focused too much on the secondary goal rather than the primary goal? To answer this we decided to test a set of modules on two groups of students: one that was instructed to use Excel to complete the module, and one that was not told what tool to use to do their calculations. We anticipated that students who were not told what to use would chose a method they were familiar with (e.g., calculator) would experience less frustration with the modules, and thus they would attain a deeper learning of the concepts in the module.
Outline of study

To study the effectiveness of spreadsheets in teaching geology and math concepts to our students the first author developed three modules that would fit into the curriculum of the Dynamic Earth: Introduction to Physical Geology course taught at USF. The three modules dealt with the following topics: density and how it varies within the layers of the Earth; buoyancy and isostasy (balance of forces between gravity pulling a floating mass down to buoyancy holding it up) and how both relate to the floating of objects in fluids and mountain building; and what forces govern landslides and how the “factor of safety” (a unitless number which gives a measure of how stable a slope is) relates to the stability of a slope.

For each module topic two different module packages were created. Both contained the exact same information and problems for the students to work through; however, one module package specified (and walked the student through) the use of Excel to complete the problems, while the other module package simply told the student to calculate the answer, so that the method of calculation was up to the student. Each module package was produced using Powerpoint to create the slides containing both the information setting up the problems and the instructions for calculating the answers. In addition, the program Articulate Presenter was used to add interactive quizzes throughout the modules to provide the students with immediate feedback on their answers. Students were not allowed to proceed past the quiz without answering all the questions correctly. Copies of the modules are included in Appendix I (see supplemental materials).

A pre-/post-module test was created for each module topic and was designed to test the knowledge gained by the student as a result of working through the module. Students who completed either the Excel module or the Non-Excel module were given the same pre-/post-module assessment tests. Before implementing the modules the pre-/post-module tests were given to an expert panel (professors and graduate students at USF) to check the validity of the questions. The tests were then modified based on the panel’s responses. In addition, the reliability of the pre-/post-module tests was judged by calculating the Kuder-Richardson Formula 20 (KR20) for each assessment test and the Cronbach alpha for each exit survey. The KR20 for the density and isostasy tests were above 0.7 and the KR20 for the landslide test was 0.6. The Cronbach alphas for each test were all above 0.66 and are thus considered reliable according to Libarkin et al. (2001) and are as follows: density module tests, 0.760; isostasy module tests, 0.903; landslide module tests, 0.846. The pre-/post-modules tests for all modules are included in Appendix II (see supplemental materials).

In addition, two versions of post-module exit surveys were created to help measure the attitude of the students after completing the module. One version
was given to the students who completed the Excel-based module and included questions about interest in the module, length of the module, comfort with the math and geology skills learned, comfort with spreadsheets, and Excel skill level (which was then classified as either novice, intermediate, or expert during data analysis). A different version was given to students who completed the Non-Excel-based modules and included many of the same questions as the Excel version. The only exception was that questions referring to spreadsheets or Excel were omitted and replaced with a question which asked the students to identify the method of calculation they used. Both versions of the exit surveys are in Appendix III (see supplemental materials).

The modules were implemented in two different sections of a physical geology lecture course in Fall 2011. One was taught by a veteran instructor familiar with the research and the modules (Class 1), and the other was taught by the author of the modules (Class 2). The two sections used the same textbook. The individual instructors prepared their own syllabus and curriculum, and so the course content was not exactly the same in the two sections. The modules and post-module tests were included as homework assignments so that all students were required to complete them at home as part of their course grade, while the pre-module tests and exit surveys were given as extra credit to those who volunteered to participate in the study. Each class was divided randomly into two groups; students in the Excel Group were assigned all Excel-based modules while those in the Non-Excel Group were assigned all Non-Excel-based modules; the groups were kept constant throughout the study. The pre-module test, module, worksheet (Excel spreadsheet or word processor document which included the student’s answers), and post-module exit survey were all available to the students through an online course system at USF. Class 1 also completed their post-module tests through the online system; while Class 2 completed their post-module tests in class the day after the assignment was due. Class 1 was assigned the density and isostasy modules, but not the landslide module as this did not fit into the course curriculum. Class 2, however, completed all three module topics. The modules were assigned to the students in the following order: density module (Class 1 and 2), isostasy module (Class 1 and 2), and landslide module (Class 2). Of the 46 students enrolled in Class 1, 34 of them volunteered for the study: 18 of these students were assigned to the Excel Group, and the other 16 were assigned to the Non-Excel Group. In Class 2, 18 of the 21 students enrolled in the course volunteered for the study, with 10 assigned to the Excel Group and 8 assigned to the Non-Excel Group. Both classes contained an even mix of science and non-science majors and were composed predominantly of freshman, sophomores, and juniors, with only a few seniors.

The results of the pre-/post-module tests, modules, and post-module exit surveys were collected and analyzed for significant changes in categories such as...
percent correct responses for pre- and post-module tests, difference in percent correct responses from pre- to post-module test, pre- and post-module test grades, and attitudes for all students, then broken up by group, and then by class. The results of these analyses are presented in the following sections. In addition, all pre- and post-module test scores for all three tests were analyzed for statistically significant differences using the statistics package SPSS and were found to be statistically different populations at a 95% confidence level.

**Module 1: Density and the Layers of the Earth**

The first module implemented in this study was given to both classes (Class 1 and 2) and focused on teaching the concept of density and how it changes with depth in the Earth. The module began by introducing the concept of density and how it relates to the packing of atoms in a substance and then discussed how the density of the layers of the Earth changes with depth. The student was also shown how to calculate the volume of a spherical shell as this was used in later calculations. The student was then taken through the steps needed to calculate the density of each layer of Earth using the thickness of each layer and the layer’s percentage of the Earth’s total mass.

The mean overall grade for all the pre-module tests was 6.8 ± 2.3 (out of a total of 13 points), while post-module tests had a mean of 10.2 ± 1.5, giving an overall gain in scores of 3.4. The gain for each class was roughly the same (~3.5 for both Class 1 and Class 2); however, Class 2 had higher mean pre- and post-module test scores than Class 1 (7.3 and 11.1 for Class 2 versus 6.4 and 9.6 for Class 1). The difference in pre-/post-module test scores by group was slight; the Non-Excel Group had slightly higher gains than the Excel Group (3.9 for Non-Excel Group and 3.0 for Excel Group).

Results of the pre-/post-module tests by question reveal a bit more. The largest gain overall (Fig. 1) was for Question 3 (formula for volume of spherical shell), while large gains were also seen for Questions 4 (largest layer volumetrically), 5 (label layers), 11 (density if volume cut in half), 12 (calculate layer densities), and 13 (calculate layer densities), all key concepts within the module. The smallest gains (Fig. 1) were for Questions 9 (density of rock on the Moon), 7 (density and layers of the Earth), and 10 (average density of Earth vs. crust). However, pre-module test scores for Question 7 were already high (~80% correct answers) suggesting that students had a good grasp on this concept before taking the module. In addition while Question 10 had both low pre-module test scores (~60% correct answers) and low gain, the post-module test scores rose to roughly 80% correct responses. The very low pre- and post-module test scores for Question 9 suggest that students did not have a firm grasp on how the density of a rock would change if placed on the Moon and that the module did not help them understand this concept better. As for results by class, students in Class 2
generally had higher pre-module test scores and/or gains for questions pertaining to geology concepts and larger gains for questions pertaining to math concepts than students in Class 1 (Fig. 2). The Non-Excel Group had a slightly higher gain for one math question (Question 12, calculate layer densities) but otherwise both groups had similar pre-module test scores and gains for all questions (Fig. 3).

Figure 1. Graph of percent correct for answers on pre- and post-module tests by question number for the density module. Each line segment represents the gain in percent correct from the pre-module test (left end of line segment) to the post-module test (right end).

Results of the exit surveys for the density module (Fig. 4) show that students in the Excel Group mainly reported a novice skill level with Excel, while Students in the Non-Excel Group reported using calculators for their calculations with the exception of one student who used Excel (the only reporting of Excel use by the Non-Excel Group for any of the modules). Student attitudes in both groups were mainly positive when asked about their understanding of the geology concepts taught in the module. Students in the Excel Group generally believed their math skills had improved and that they would be able to apply those skills elsewhere, while students in the Non-Excel Group were not so sure. Both groups of students were split on their level of interest in the module, the difficulty of the module, and the length of the module, with about half as many leaning towards positive attitudes as towards negative attitudes. The results also show that both groups were frustrated while working on the module but that the Excel Group was much
more frustrated than the Non-Excel Group. Lastly, neither group said they would recommend the modules to be used in other college-level courses and neither wanted to do more modules.

Figure 2. Graph of the pre- to post-module percentage-point increase in the percent correct answers by question and categorized by class for the density module. (Each bar is % of the class correct on the question for the post-module test minus % of the class correct on the question for the pre-module test.)

Figure 3. Graph of the pre- to post-module percentage-point increase in the percent correct answers by question and categorized by group for the density module.
To summarize, students generally did well on questions pertaining to identifying a formula that they were likely first exposed to in the module (volume of spherical shells), identifying layers of Earth, understanding how the equation
for density works, and calculating densities, all key concepts in the module. Students didn't do well on the questions relating to how the density of a rock would change if it were on the Moon, suggesting that the module did not help students understand this concept. This could be addressed by adding a slide or footnote regarding the difference between mass (which does not depend on gravity and is used in the density equation) and weight (which does depend on gravity and is not included in the equation for density). For all other questions pertaining to density, students had high pre-module test scores and moderate to low gains, suggesting students already had this knowledge before attempting the module and the module served to strengthen that knowledge. Which group the student was in did not appear to have much of an effect on learning for this module, while which class the student was in had a significant effect on learning. As for attitudes, students for the most part felt very comfortable with their level of understanding of the geology and math concepts after taking the module, which matches well with the high gains in pre- to post-module tests scores for geology and math-based questions. However, attitudes toward the module as a whole were either split or low, with most students stating that they did not enjoy the experience and would not like to repeat it.

Module 2: Building Mountains: Isostasy

The concepts of buoyancy, isostasy, and mountain building were explored in the second module implemented in both classes. The students were first introduced to the concept of buoyancy by investigating blocks of wood and/or cork floating in water and guided through the steps necessary to calculate the height of the blocks above and below the water surface. The calculations were made more complex by adding layers of different wood to the blocks and then changing the stratified blocks of wood into stratified Earth blocks made of lithosphere immersed in asthenosphere. The concepts of isostasy (balance of forces holding a mass up in a fluid versus forces pulling the mass down into the fluid) and mountain building were explored using the Airy and Pratt models of isostasy. The students were asked to perform calculations using similar geologic circumstances but with first the Airy and then the Pratt equations and then asked to think about which theory applied better for different crustal sections (e.g., continental versus oceanic crust). Finally, the students were given real-world examples and asked to calculate the root of the Himalayas using the Airy equations and the thickness of oceanic crust using the Pratt equations. This module also built on knowledge about density that the students had attained from the first module.

The overall average score for all students in both classes for the pre-module test was 5.5 ± 2.4 (out of a total of 13 points) and for the post-module test was
10.1 ± 2.7, with a gain of 4.6. Students in Class 2 had higher gains and higher post-module test scores than students in Class 1 (5.9 and 11.0 for Class 2 pre- and post-module test scores, respectively, versus 3.5 and 9.4 for Class 1 pre- and post-module test scores, respectively). Average post-module test scores for the Excel Group and the Non-Excel Group were identical (10.1); however, the Non-Excel Group had lower pre-module test scores (5.0 versus 5.9, Non-Excel Group and Excel Group, respectively) and thus a larger gain (5.1 and 4.2 for Non-Excel Group and Excel Group, respectively).

![Figure 5](image.png)

**Figure 5.** Graph of percent correct for answers on pre- and post-module tests by question number for the isostasy module. Each line segment represents the gain in percent correct from the pre-module test (left end) to the post-module test (right end). “Pratt” and “Airy” refer to different classic models of isostasy, and $h_r$ and $h_m$ are specific variables: the height (thickness) of the root of the mountain and height of the mountain, respectively.

Gains by question were generally very high, particularly for questions involving calculations (Fig. 5). Eight out of a total of 13 questions had gains of 37-68% correct responses. The largest gains were for Questions 4 (which model assumes density varies laterally?), 7 (how does material density affect root?), 8 (difference between Pratt and Airy models of isostasy), 9 (why does Pratt explain oceanic crust better?), 10 (what is the point of the root?), 11 (calculate $h_r$ and $h_m$, variables used in the module which are the height of the root of the mountain and height of the mountain, respectively), 12 (calculate $h_r$ and $h_m$), and 13 (calculate...
all key concepts from the isostasy module. The lowest gains were for questions relating to density; however, there were also high pre-module scores for these questions as well, suggesting that students already had a good understanding of density before completing the isostasy module which was likely due to the knowledge gained from the first module. Students in Class 2 again had higher gains for most questions, particularly the math concept questions, and to a lesser extent the geology concept questions (Fig. 6). Students in both the Excel Group and Non-Excel Group had significant gains in questions related to math and geology concepts covered in the module; however, the Non-Excel Group had slightly higher gains (Fig. 7).

Figure 6. Graph of the pre- to post-module percentage-point increase in the percent correct answers by question and categorized by class for the isostasy module. (Each bar is % of the class correct on the question for the post-module test minus % of the class correct on the question for the pre-module test.)

Exit surveys (Fig. 8) showed that students in the Excel Group believed themselves to now have novice to intermediate Excel skills and students in the Non-Excel Group now all reported using calculators as their means of calculation. Overall, all students felt they learned the geology and math concepts well and believed they could apply their new math skills elsewhere. In addition, students generally felt the module was interesting and worth their time; however, they thought it was too long. Students in both groups were not sure if the skills they
had learned were valuable and neither wanted more modules. As for reported levels of frustration, students in the Excel Group were somewhat frustrated while those in the Non-Excel Group were very frustrated.

In summary, the largest gains were for math concept questions. Questions relating to the concept of isostasy had high gains as well; however, these gains were slightly lower than for the math concept questions. Again, which class the student was in had a much larger effect on learning than what group the students was in, with students in Class 2 having the best gains overall and students in the Non-Excel Group having slightly higher gains than those in the Excel Group. Questions relating to density had much lower gains but higher pre-module scores, again suggesting that students had this knowledge before attempting the modules. Overall this module did an excellent job teaching math concepts to the students and a good job teaching geology concept to the students, which is not so surprising considering that isostasy is a difficult concept for many students to master. Students’ attitudes toward the modules again reflected that students felt comfortable with the geology and math concepts they had learned in the module, which again was reflected in the pre- and post-module scores for these concepts. Also, frustration levels were high, and students generally did not want to repeat their module experience; however, overall, students felt it was worth their time.
Figure 8. Histograms of the results of the exit surveys separated by questions and categorized by group and class for the isostasy module. The histograms are all plotted on the same scale.
Module 3: Landslides! Slope Stability and the Factor of Safety

The final module used in this study was given only to Class 2 as it did not fit into the curriculum of Class 1. The module focused on slope stability and how it is determined using the factor of safety. Students were introduced to the concept of gravitational force acting upon a block on an inclined plane. They were then walked through how the normal force and shear force related to the gravitational force. Friction and cohesion were discussed, and students were asked to think about what changes might come when wetting sand versus clay. Students were also introduced to the concept of stress in the form of the equations for normal and shear stress. Finally, the module explored the equation for the factor of safety and how this unitless number relates to the stability of a slope. Students were then guided through the calculation of the factor of safety for a block on a slope under dry conditions and then under saturated conditions and asked to discuss what effect the saturation had on the stability of the slope. They were asked to re-calculate the factor of safety after changing the angle of slope to investigate how stability changed with slope angle. It was in this module that the Excel spreadsheets were the most useful, as the formulas for the dry versus saturated conditions were very close and thus easily copied from one cell to another. However, most importantly, changing the angle of the slope in Excel was met with an instant change in the factor of safety thus providing immediate answers, while students who were in the Non-Excel Group were forced to redo their calculations which was quite labor intensive and likely frustrating.

The average grade for pre-module tests was 5.6 ± 2.9 (out of a 13 total points) and 9.5 ± 1.5 for post-module tests. Students in the Non-Excel Group had larger gains than those in the Excel Group (4.2 versus 3.6 for the Non-Excel Group and the Excel Group, respectively) but lower pre-module scores (5.2 versus 6.0 for the Non-Excel Group and Excel Group, respectively).

Results of the pre-/post-module tests by question (Fig. 9) revealed that the largest gain overall was for Question 12 (calculation of factor of safety), while Questions 1 (Factor of safety and stability), 2 (Force and stress), 5 (Influences on stability), 6 (How to increase stability), 11 (Saturated vs. dry materials), and 13 (Calculation of force from stress) all had large to moderate gains. Students in the Non-Excel Group (Fig. 10) had slightly higher gains for Questions 1 (Factor of safety and stability), 3 (ID angle of slope), 4 (cohesion for clay vs. sand), 7 (influence of increasing force on stress), 9 (is slope angle only factor affecting stability?) and 10 (influence of increasing cohesion on stability), while those in the Excel Group had higher gains on Questions 13 (calculation of force from stress), 5 (influences on stability), and 11 (saturated vs. dry materials).
Figure 9. Graph of percent correct for answers on pre- and post-module tests by question number for the landslide module. Each line segment represents the gain in percent correct from the pre-module test (left end of line segment) to the post-module test (right end).

Figure 10. Graph of the pre- to post-module percentage-point increase in the percent correct answers by question and categorized by class for the landslide module. (Each bar is % of the class correct on the question for the post-module test minus % of the class correct on the question for the pre-module test.)
Figure 11. Histograms of the results of the exit surveys separated by questions and categorized by group and class for the landslide module. The histograms are all plotted on the same scale.
Results of the exit surveys (Fig. 11) again reveal that students in the Excel Group generally identified their Excel level as novice to intermediate and those in the Non-Excel Group used calculators throughout the module. Students in both groups were comfortable with the geology concepts they had learned in the module, and they generally believed they improved their math skills; however, students in the Excel Group were split between believing and not believing their skills improved. Again students in the Excel Group felt they could apply their math skills elsewhere, while those in the Non-Excel Group were not so sure. Overall, students felt the module was worth their time, but did not want to do any more. Students in the Non-Excel Group believed the module was interesting while those in the Excel Group were neutral on interest. Generally students in the Excel Group thought the module was too long, while those in the Non-Excel Group did not think it was too long. In addition, students in the Non-Excel Group felt the skills they had learned in the module would be valuable elsewhere while those in the Excel Group did not. Frustration levels were high for students in the Non-Excel Group but split between high and low for students in the Excel Group.

Overall, questions relating to the factor of safety and calculations using the factor of safety had the largest gains. Questions relating to how the factor of safety measures stability and general influences on stability had moderate to high gains. Questions 2 (force and stress) and 3 (ID angle of slope) had moderate to high gains; however, both pre- and post-module test scores were low for these questions, suggesting that the module had a somewhat positive effect on learning for these subjects, but not nearly as high as we would have liked. Students generally had small gains for questions pertaining to the effect of angle of slope and material on stability; however, these questions also had high pre-module scores suggesting students already had a good understanding of these concepts before taking the module. For this module there were some differences in gain by group (as listed above); however, it is unclear what (if any) the link is between these questions and which group the student was in. As with all modules, students generally felt comfortable with the geology and math concepts; however, some students in the Excel Group did not feel their math had improved. Students were very split on their interest in the module and whether the skills they learned were valuable outside of class, with students in the Non-Excel Group much more positive than those in the Excel Group. Again, as with all previous modules students felt that the module was worth their time but did not want to do any more modules.
Discussion

This study shows that, overall, students had high gains in knowledge for the main concepts presented in the modules, particularly for questions involving computation (gains of 28-68 percentage points). The gains for the computational questions in the isostasy module were the highest (gains of 54-68 percentage points), while those for the density module were the lowest (gains of 28-35 percentage points). This may be due in some part to the fact that the density module was given first and so students were getting used to how the modules worked or it may stem from the fact that the isostasy module built on the knowledge gained in the density module.

Students in Class 2 overall did much better on the pre- and post-module tests and had the highest gains per question particularly when it came to the math concept questions. This may be explained in a number of ways; first who taught the course may have had an effect (i.e., taught by the author of the modules or not). Students in Class 2 were taught by the author of the modules, and those in Class 1 only met with the module author twice throughout the semester. The instructor in Class 1 did not mention anything about the modules in class, while the instructor of Class 2 often reminded students how what they were learning in lecture would be looked at more deeply in the modules. For instance, when discussing landslides and the angle of repose, the instructor of Class 2 informed the students that the module they would be working on for homework would go into much more detail about this subject. In addition, as the students in Class 2 saw the author of the modules much more frequently than those in Class 1; the students formed a closer bond with the instructor and thus felt much more comfortable asking questions in class or over email, while those in Class 1 mostly avoided emailing the module author despite being reminded often of the availability. The disparity was evident in the comments made on the exit survey, which contained two sections where students could voice their opinions of what they liked or didn’t like about the module. Comments from students in Class 2 were much more respectful even when the comments were negative, while numerous students in Class 1 used an uglier style of language, different in both tone and word choice (both positive and negative comments).

In addition, students in Class 1 completed their post-tests online immediately after submitting the module, while students in Class 2 completed the post-module tests in class the next class day after the module was due. This brings up a two-fold issue. First, students in Class 2 had time for the material to “sink in” while those in Class 1 did not. Does a lag time affect responses? Second, students in Class 1 may not have taken the post-module test as seriously because it was administered online. The informality of the testing itself may have contributed to
the gap in learning between classes. Are online-administered assessment tests as reliable as in-class tests?

The only module where there were slight differences in learning between groups was the landslide module. The Excel Group had slightly higher gains on Questions 13 (calculation of force from stress), 5 (influences on stability), and 11 (saturated vs. dry materials), questions dealing with calculations of force and how water affects the stability. While the Non-Excel Group had slightly higher gains for Questions 1 (Factor of safety and stability), 3 (ID angle of slope), 4 (cohesion for clay vs sand), 7 (influence of increasing force on stress), 9 (is slope angle only factor affecting stability?), and 10 (influence of increasing cohesion on stability) or questions pertaining to the slope angle, cohesion, and influence of force. It is not clear why there was a difference in gains for these particular questions and as this was the only module in which there were noticeable differences in gains between groups, it may simply be a coincidence.

As for student attitudes towards the modules, a few things are clear. First, students felt comfortable with both the geology and math concepts they were learning in each module after completion of the module. This is also reflected in the high gains for questions pertaining to the geology and math concepts. These results are encouraging as it appears that students are doing well and feeling more confident about the main subjects presented in the modules, despite any real or perceived difficulty. Another interesting result was that, overall, students in the Excel Group felt no more negative than students in the Non-Excel Group about being able to apply the math skills they had learned elsewhere. This appears to be due to the use of Excel as the calculation tool. Students in the Excel Group may have felt a large sense of achievement upon using Excel to complete the module due to the sharp learning curve. In addition, students in the Excel Group may also have recognized the value of using Excel to solve equations in other classes (or aspects of life) which may have contributed to their positive outlook. Finally, although many students (in both groups) agreed that the modules were worth their time, they were adamant that they did not wish to do further modules and would not recommend the modules to other college classes.

This study was intended to determine whether one reason for disliking the modules is the sharp learning curve associated with using Excel for the first time. However, as we have shown, the use of Excel does not appear to have a negative effect on learning. We must now consider the question that perhaps the use of these modules is similar to the idea that even though we know that exercise is good for our well-being, many of us hate doing it. In other words, the problem underlying student disgruntlement toward the modules may be simply dislike of math in general and a tendency in the students towards math avoidance. The idea of the resistance of students to the introduction of math into the geosciences classroom is not new; several studies have elaborated on the idea that geology is
traditionally thought of as a more qualitative and less quantitative subject (Wenner et al., 2009; Wagner, 2000; Lutz and Srogi, 2000). However, despite the tendency for students who sign up for geology courses to be shocked by and uncomfortable with any math concepts included in the curriculum, it is still necessary to include a quantitative component in any introductory geology course. Some studies suggest a more veiled approach to including quantitative concepts in geosciences courses (Wagner, 2000). Using spreadsheet-based modules is a more direct method that may appeal to instructors who wish to be explicit in communicating the need for math in understanding geology.

Although we suspect that many of the discouraging comments from students were made as a result of an ingrained tendency towards math avoidance, the study highlighted some issues with the modules unrelated to math avoidance. Foremost is student frustration due to a lack of Excel skills, which would be helped by the addition of an Excel primer to the curriculum in classes in which these modules are used. Additional suggestions arising during our study and the students’ comments on the exit survey are: Shorten the modules and make them less dense; add more examples of how to use the equations presented; add practice problems after each section in the modules in addition to the End-of-Module questions; add quizzes or self-correcting spreadsheets to give students immediate feedback. Suggestions for future studies needed to assess the effectiveness of the modules are: Test the modules in courses that are not taught by the author; test the effectiveness of assessments given online versus in class; test versions of the modules that have been shortened; have more examples, including practice problems; test the effectiveness of all-online and interactive versions of the modules; and finally track student retention of the material after leaving the course.

**Conclusions**

In conclusion, we have shown that the modules used in this study did a good job of teaching the main math and geology concepts illustrated in each module, and that students generally felt confident in their newly obtained knowledge of these subjects. Also, there were very few instances where the type of tool used to perform calculations (e.g., Excel or calculator) had much of an effect on the level of learning, suggesting that despite complaints about the steep learning curve when using Excel for the first time, it does not appear to affect learning. However, our results did show that the most important factor for improving the depth of learning with the modules was which class the student was in. This result is a bit perplexing as these modules were created with the intent that they could be used by any instructor, but it appears that the level of learning is, in some way, tied to who is teaching the class. Whether or not this effect would remain if
modules were used that were not written by the instructor is an obvious question that requires future work. Another confounder is that the modules developed for this study were on the challenging side as compared to other modules included in the SSAC collections, and this may have increased the frustration of the students. However, it is important to note that despite the challenging nature of the modules, the students still had substantial gains in their knowledge of the geology and (particularly) the math concepts presented in the module.

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