The Big Crunch: A Hybrid Solution to Earth and Space Science Instruction for Elementary Education Majors

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ABSTRACT

We describe the rationale and process for the development of a new hybrid Earth and Space Science course for elementary education majors. A five-step course design model, applicable to both online and traditional courses, is presented. Assessment of the course outcomes after two semesters indicates that the intensive time invested in the development of the course results in a manageable workload during the semester for faculty with an already full teaching load. We also found that average scores in proctored online exams for this cohort of students are identical to the average scores of students from the same major enrolled in a face-to-face (F2F) course. Exam scores significantly improved in the second semester after adjustments to the workload and the introduction of explicit test-taking tips at the beginning of the semester. We found that our students, at all stages of their studies, were not used to the self-guided instruction required for success in online courses, and were often not as comfortable using Web-based technology for instruction as we expected.
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Key Words: Earth and Space Science, preservice teachers, elementary education, hybrid course, distance education

INTRODUCTION

In this paper we describe the process that has led to the creation of a new hybrid (online plus face-to-face [F2F] instruction) Earth and Space Science (E&SS) course for elementary education (ElEd) majors at Iowa State University (ISU), and describe some of the lessons learned from the first two semesters of teaching the course. ISU is a rural, research-intensive Midwestern university with a student population close to 30,000 that has been growing steadily since 2007. The average teaching load for faculty in science departments ranges between seven and nine credits per year, with class sizes that have been growing because higher enrollments have not been matched by higher number of faculty. Online courses are offered but this is not the primary mode of course delivery. Given future projections for enrollments in higher education institutions across the country (NCES, 2011), the model described here will possibly become a more common approach to manage faculty teaching loads with reduced resources.

After briefly reviewing the rationale behind the creation of the course, we discuss the development process used for both the online and F2F parts of the course. We then describe results from the first semester of teaching, specifically looking at the effect on the teaching load for the faculty involved and how students in this course compared in learning science content with those in a more traditional course. Finally, we discuss some lessons learned from the first semester highlighting those challenges particular to a hybrid course and to our target cohort of mostly on-campus freshman ElEd majors, and share the results of these changes at the end of the second semester.

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RATIONALE FOR COURSE DEVELOPMENT

In 2009, the State of Iowa introduced new program requirements for beginning elementary teachers, effective September 2015. Given the standard four year preparation, these changes mean that, beginning college in Fall 2011 (F11), ElEd majors had to follow a course of study aligned with these new requirements (IBEE 2011; Iowa DOE 2012; see supplemental file available at http://dx.doi.org/10.5408/12-335s1). The new requirements state that nine semester hours (e.g., 3 three-credit single semester courses) in science content have to be equally distributed among life sciences, physical sciences (chemistry and physics), and E&SS. In addition, students are required to take three semester hours of science methods that include "current best-practice, research based methods of inquiry-based teaching and learning of science" and "integration of technology in teaching and student learning in science" (see supplemental file).

Previously, students could choose to fulfill the nine-semester-hour science content requirement by choosing from a list of several science courses, traditionally selecting courses like physical geology, astronomy, biology, or meteorology. From our discussions with various ElEd academic advisors at ISU, we know these courses were perceived as less challenging than physics or chemistry.

The transition to the new requirements was particularly problematic for E&SS faculty because the science content required by the State was spread over 3 three-credit courses (Introduction to Astronomy, Introduction to Physical Geology, and Introduction to Weather and Climate). It quickly became apparent that a new E&SS course would need to be developed aimed specifically at our ElEd majors. At ISU the major challenge was how to add this new (required) course to the essentially full teaching load of the E&SS faculty involved. To meet this challenge and ensure student engagement with the material, we designed a hybrid course model consisting of a two-credit online course incorporating multiple active learning opportunities and a one-credit (two-hour) F2F inquiry-based lab designed specifically for ElEd majors.

DEVELOPMENT OF THE ONLINE COMPONENT

Content Experts Meet Curriculum Designers and User-Centered Design Specialist

Like many institutions of higher education, ISU is encouraging the development of online courses. This has led to the proliferation of online courses delivered through various platforms and developed using a variety of approaches. To navigate through this complex jungle and to ensure the self-sustainability of the course, the two content experts (a geologist and an astronomer) partnered with two curriculum designers and one user-experience specialist for the development of the online component of the course.

The team was tasked with creating a vision for meaningful learning experiences in the course that met specific curriculum goals and standards, focused on student needs, utilized available resources, and monitored for both student learning and effectiveness of teaching practices. A multiphase design model was used to help us understand how to guide instructional decision making. Although a number of curriculum design models favor a systems approach in which a sequence of procedures must be followed to ensure that learning occurs (Dick et al., 2001), we viewed the instructional design process as recursive and nonlinear.

The design and development of the course's online component moved through the following phases:

1. **Context:** This phase involved collaborative, reflective, incremental, and organic planning of the prospective course climate and student and teacher expectations. The team explored the larger landscape of elementary and early childhood teacher preparation, and issues surrounding professional careers of new science teachers.
2. **Pedagogy:** This phase was marked by the construction of the pedagogical framework within which meaningful teaching and learning experiences in the course ought to occur. At this stage we defined the main objectives and logistics. The pedagogical phase was largely shaped around the themes from a comprehensive literature review (Davis et al., 2006) that probed into an array of challenges encountered by new science teachers. Specifically, the pedagogical decisions in this course were designed to address the known problem areas, such as:

   a. Challenges associated with student comprehension of domain-specific knowledge, including students' previous science backgrounds and inherent beliefs about scientific inquiry and the nature of science. Research on preservice elementary teachers revealed that new professionals tended to hold a number of fundamental misconceptions about science, and that their science teaching efficacy was lower for those individuals with more pervasive misconceptions (e.g., Schoon and Boone, 1998). Research on elementary teachers demonstrated that a majority possessed a negative attitude towards science (e.g., Feistritzer and Boyer, 1983; Pedersen and McCurdy, 1992; Bleicher, 2009) and that such negative attitudes were passed onto young learners (e.g., Scharmann and Orth Hampton, 1995). The emphasis on reading and math in No Child Left Behind ultimately resulted in even less emphasis on science in elementary education (e.g., Dove, 2010).

   b. Challenges associated with student knowledge of how others learn, including student recognition of multiple ways in which young learners create frameworks of reference.

   c. Challenges related to recognition of what constitutes meaningful instruction and how it is dependent on teacher knowledge, beliefs and understanding of effective learning environments, teaching and learning strategies, approaches, and representations.

   d. We were committed to modeling inquiry-based learning, hence group work and inquiry-based habits (such as data verification) were highly encouraged. Based on the above goals and following a philosophical approach similar to the one described in Totten (2008) for the training of science-expert teachers, our approach included comprehensive E&SS content, group work and inquiry-based learning opportunities, simple multimedia visuals (diagrams, maps, photos, and short videos) to augment text, and valuable learning resources (a comprehensive textbook, Marshak, 2008). Thus, our major objectives were: (1) To cover the K–5 E&SS content requirements at sufficient depth so that prospective K–5 teachers would be very comfortable teaching to young learners; (2) To focus on the three main "big ideas" of E&SS literacy (Wysession et al., 2009) throughout the course in addition to providing ample opportunities to experience science and become familiar with the nature of science (e.g., Clough, 2011). While this second objective more readily fitted within a lab setting, it was decided that the experiential components in the online component could be used to present simple experiments that did not require expensive equipment or complex setups; and (3) To model the kind of effective teaching that would be transferrable to classroom situa-

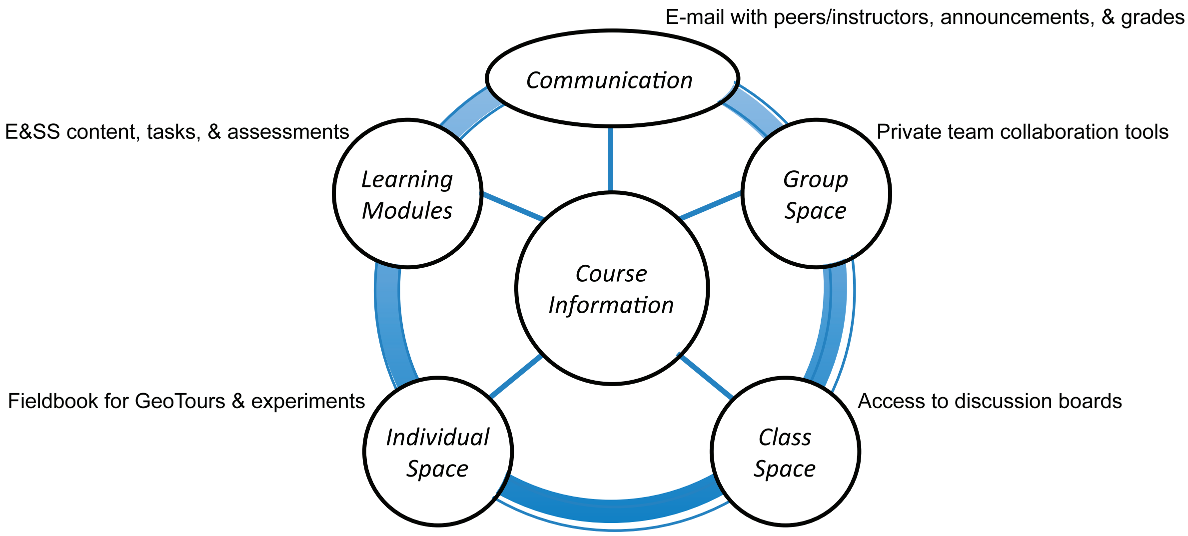

FIGURE 1: Online course design schematic. Students enter the course at "Course Information," which contains items like the syllabus, class schedule, learning objectives, and instructor contact information. Navigation between various sections of the course, indicated by the connecting lines, is very flexible; a student can move between any two sections of the course in one step.

tions for young learners with multiple representations of the subject matter.

3. **Technology:** We were acutely aware of a pedagogical challenge unique to the course—teaching and learning online—that required careful consideration of the kind of content, interaction, and pedagogy that would work together to set this course apart from prospective student traditional classroom experience. This phase involved translating the pedagogical vision into technological solutions that would create an authentic inquiry-based learning environment. Beyond making obvious some important technological choices, such as utilizing a suitable platform for course delivery and management, we worked together to reconcile the pedagogical vision of the course within the limitations posed by available technology. Ideally, the technological solutions would transcend the deficiencies of traditional classroom learning. In reality, technology could not be applied simply to pedagogy. Developing such a nuanced role of technology left us satisfied with several choices and dissatisfied with others, such as the development of a highly interactive content delivery system.
4. **Impact:** This stage involved the analysis of course assessment and student assessment data. Several feedback options were integrated into the course's online environment in order for students to share their opinions on the design of the course. We monitored student participation in the various components of the course by both formative and summative collection of student assessment data.
5. **Adjustment:** We classified student and teaching feedback and designed viable interventions. Some were applied immediately to improve the course's ongoing experience; others were postponed until the next iteration of the course.

The course development process took approximately one year. Three-quarters of the time was spent researching literature on distance learning and preservice elementary teachers, interviewing colleagues, reviewing sites (such as the one put together by On the Cutting Edge project on the Science Education Research Center [SERC] website, http://serc.carleton.edu/NAGTWorkshops/online/), and assembling a summary of best practices from what we found.

The final design of the online part of the course is illustrated by the schematic shown in Fig. 1. One highlight of the design is the balance between individual work, in Learning Modules and Individual Space, and group work and peer interaction, in Group and Class Spaces. While we assumed that most of the online learning would be done individually, we designed activities that would require students to learn collaboratively, including team-based discussions and science experiments. A communication section for student–student and student–instructor interaction and a general course information section providing a centralized storehouse of vital documents round out the design.

In the next section we discuss how this design was realized as an online course using Blackboard Learn 9.1, the course management software at ISU. While the use of this system led to some strong constraints on the overall look of the course, this was more than balanced by considerations of the support and long-term sustainability of the course.

The Product

The basic unit for content delivery in the online component of the course was the weekly learning module that covered aspects of E&SS that are conceptually related, such as lunar phases, tides and coastlines, or minerals and

FIGURE 2: Sample learning module. This screenshot illustrates the structure of a typical learning module. Learning objectives for the module are given at the top of the page along with any time-sensitive reminders. Students then explore the weekly topic in more detail following the directions in the Learn column. The Exploration column contains links to related activities such as experiments or Geotours, and the Discuss column prompts students to participate in the weekly discussion. Links to other parts of the course are found at the bottom of the module and on the main navigation bar to the left that remains in place throughout the student's session.

TABLE I: Online module topics.

Week	Module Content
1	Course Introduction/Orientation
2	Minerals and Rocks, Part 1
3	Minerals and Rocks, Part 2
4	Geologic Time
5	Erosion and Weathering
6	Landslides and Volcanoes
7	Plate Tectonics, Part 1
8	Plate Tectonics, Part 2
9	Earthquakes
10	Water
11	Lunar Phases, Tides, and Coastlines
12	Weather and Climate
13	Climate Change
14	Earth's Interior
15	Solar System

rocks (see example in Fig. 2). In total, there were 14 E&SS content modules along with one module devoted to an introduction and orientation to the course (see Table I). The content covered in the course was similar to what is addressed in other E&SS courses (e.g., Avard 2009), including material like weather and climate, lunar phases, and the solar system, in addition to topics typically included in a traditional physical geology course.

Each of the learning modules had the same basic structure. The top part of the page listed the Learning Objectives for the module and included time-sensitive reminders about course-related activities, such as quizzes and exams. Below the Learning Objectives section, three columns labeled Learn, Exploration, and Discuss listed instructions on what readings to do, links to additional online only content, links to associated experiments, and instructions on completing a weekly discussion question.

The course was designed with a rather rigid weekly timeline of tasks outlined in Table II. Each task was carefully selected and designed to ensure that students were challenged academically and involved in active learning—two fundamental aspects of student engagement measured, for example, by the National Survey of Student Engagement (Kuh, 2009).

The core content was delivered using required textbook readings combined with online-only material that highlighted and developed key points from the readings through additional diagrams, animations, videos, and brief text summaries.

Students were divided into teams of four at the beginning of the semester based on the information given in a survey on learning preferences, background, and grades that they would like to teach. Each team was required to meet for one "experiment" (the campus rock hunt), to collaborate on the development and posting of one weekly question during the semester, and on posting a team answer to each week's question. Each team consisted of at least one investigator charged with finding data and information for the weekly question, one reporter who was responsible for summarizing the team's answer and posting it, and a skeptic who ensured that the content of the posting was scientifically sound and at least two reliable sources were properly cited. Students were encouraged to take turns in these roles, practicing fundamental components of scientific research and team-based work, including the critical assessment of material found online and the students' primary source of information.

We also included a number of simple, "kitchen-based" (i.e., low cost, minimal equipment) experiments and Google Earth explorations (Geotours; Wilkerson, and Marshak, 2008) to be recorded in individual e-fieldbooks (Table III). The goal of including simple experiments was fourfold: (1) to provide the ElEd students with concrete examples of very simple demonstrations that they could one day carry to the classroom; (2) to help them develop their skills in observing and taking notes on what happens during an experiment; (3) to give ElEd students the opportunity to actively engage in multiple and varied activities outside the online content; and (4) to introduce Google Earth as a wonderful E&SS educational tool and a good example of the use of technology in teaching. To assist students who had problems procuring the material needed for the experiments, we assembled "experiment kits" for the students to check out for a nominal fee.

In addition, students were asked to try their hand at weather forecasting using the Dynamic Weather Forecaster (Cervato et al., 2009, 2011) and to record five different Moon phases in their e-fieldbook. Again, these activities were included to help students connect the course reading material with the real world, give them experience with data collection, and give them ideas of activities that they could use with their students in the future.

Table II: Weekly timeline for online portion of course.

Day of the Week	Tasks and Deadlines
Weekend	Complete assigned textbook reading; submit weather forecast and record Moon phase.
Monday	Complete diagnostic self-assessment; team prepares question for discussion posting.
Tuesday	Begin experiment/Geotour and record in e-fieldbook; post discussion question.
Wednesday	Review online content module; work with team to research material for answer to weekly discussion question.
Thursday	Complete team work and post response to weekly discussion question.
Friday	Complete graded quiz; assess responses to weekly discussion question.

Table III: Experiments and Geotours.

Experiments	Geotours
Boiling water modified after Riker-Coleman et al. (2010)	Volcanoes and related landscapes
Campus rock hunt (in teams)	Continental drift
Plaster of Paris and freezing water	Plate boundaries
Principle of superposition with a deck of cards; half-life of decaying isotopes and coins	Faults and earthquakes
Stream gauges, hydrographs, and evaporation of salt water	Coastlines
Daylight duration at solstices and equinoxes and latitude	Terrestrial impact craters
Water condensation and cloud formation in a bowl	
Build a scale model of the Solar System with a strip of register paper	

Every component of the course was included in the assessment (Table IV). Self-assessment and quiz questions were selected from the two test banks provided by the textbook publisher and imported onto Blackboard. The only proctored assessment consisted of four regularly spaced exams to be taken at a distance learning facility. Since these students are on-site, this did not create logistical problems. Questions for the 30-item exams came from the same pool used for the weekly graded quizzes.

Since we were aware that the online content delivery was new to most of our students, we used the Early Warning tool in Blackboard to flag students who had not accessed the course for more than 7 days. We sent these students an e-mail reminder of the importance of regular involvement with the online material for their success in the course.

DEVELOPMENT OF THE LAB COMPONENT

The focus on learning-by-inquiry was the main reason behind the choice of a hybrid course that includes a 2-hour lab component. Taught by a teaching assistant, each weekly lab loosely follows the content in the online component (Table V) and each activity is based on one or more of the learning objectives identified for the online course. Without the assistance of a lab manual, students are involved in group activities designed to model scientific inquiry and to actively engage them. With a modest investment in basic supplies like lenses, crayons, tree slices/cores, and coins, along with maps of the Earth, ocean floors, and the Moon, downloaded from the NASA and USGS web sites, we outfitted the lab with materials for the students to work with.

TABLE IV: Online portion assessment.

Assessment	Cumulative Weight (%)
Team-based weekly discussions	15
Graded quizzes (best 13 of 15)	15
Proctored exams (4 @10% each)	40
Diagnostic self-assessment (unlimited attempts)	5
Experiments and Google Earth Geotours	15
Moon phase recordings (5 required)	5
Weather forecasting (10 required)	5

We adapted a 2-week plate tectonic lab developed by D. S. Sawyer (Sawyer et al., 2005) and developed other activities from the literature and our own teaching experiences. Weekly meetings between the faculty and the teaching assistant (TA) were held to review the current week's lab and prepare for the following week's lab. Detailed notes of each lab session were kept with the idea that these will be developed into a TA guidebook in future semesters.

Each lab session is based on learning objectives identified for the online course and lab requires students to work in groups of four. In the plate tectonics lab, for example, students are given maps of earthquake epicenters, modern volcanoes, sea-floor age, and topography and bathymetry. Each group works with one map to identify possible plate boundaries. One student from each group then forms new groups of four where students share what they learned from their map, and compare and combine their results to come up with a new map of plate boundaries. Groups share their findings with the class and then they compare the student-produced maps with a plate boundary map provided by the TA. Finally, students use the collective information to identify the types of plate boundaries of a particular plate (Sawyer et al., 2005).

To address known misconceptions on the nature of science directly, five homework activities were assigned using materials from the Story Behind the Science project (http://www.storybehindthescience.org; Clough, 2011). Each story describes the history behind different scientific discoveries and theories, and includes four open-ended questions designed to get students to think more about the nature of science. Each assignment is worth 20 points, graded using a rubric made available to the students at the beginning of the semester. To ease the grading burden, the student marks one answer that he or she would like the TA to grade and the TA picks one of the other questions. The cumulative scores in the homework were 25% of the final grade. Students submitted their classwork after every lab period. This work was marked on a complete/not complete scale but the TA would occasionally deduct points for work that was clearly sloppy and indicative of not fully participating in the lab. The lowest score of the 14 sessions was dropped and this component was worth 50% of the final grade. The remaining 25% was based on three short quizzes that were administered during the first 15 minutes of a lab session. Students were given a brief study guide the week before each quiz reminding them of the topics to be tested.

TABLE V: Lab structure for Spring 2012 semester.

Week	106L Topic	106L Quiz	106L Reading Due Date
1	Nature of Science		
2	Mineral ID		
3	Rock ID, Rock Cycle		
4	Relative Dating	Quiz 1: Mineral and Rock Identification	
5	Absolute Dating		
6	Combining Dating Techniques		A Very Old Question: Just How Old is the Earth?
7	Continental Drift		
8	Plate Tectonics		Continents: A Jigsaw Puzzle With no Mechanism
9	Earthquakes		
10	Moon/Seasons		Data Do Not Speak: Development of a Continental Drift Mechanism
11	Water 1		
12	Water 2	Quiz 2: Dating, Tectonics, Seasons	
13	Climate Change		
14	Earth's Interior		
15	Solar System	Quiz 3: Water, Climate Change, Earth's Interior	

In addition to E&SS content knowledge questions, each quiz also included at least one question that directly addressed nature of science issues. For example, one such question from the first quiz was, "We used crayons to model the rock cycle. What are some examples of other models scientists use? What do scientific models help scientists do?"

COURSE TESTING—SEMESTER 1

The course was taught for the first time in Fall 2011 with an initial enrollment of 48 students divided into two lab sections of 24. Our first hypothesis was that a hybrid course has a lower workload for a supervising faculty member compared with a traditional lecture–lab course. To test this, we kept track of the amount of time spent managing the course during the semester. Quizzes, exams, deadlines, automatic releases and announcements, grading rubrics, and the grade center were all set up before we launched the course and required approximately one month of intensive work including the learning of a new (for the instructors) course management platform. Compared to this, the time needed to manage the course during the semester was minimal, on the order of 3–4 hours per week including a weekly meeting of the two instructors and the teaching assistant to assess course progress and make plans for the lab.

Blackboard automatically monitors all students' activities and allows instructors to identify students who have not been active in the course for a selected number of days and to contact them. Each week the instructors graded discussion questions and answers: after doing this together for the first three weeks to calibrate our ratings, we took turns grading discussions in alternate weeks. Other occasional activities included answering students' emails, making arrangements with the testing facility, and posting occasional reminders of upcoming activities or on issues that had come up in emails that we received from students.

Our second hypothesis was that students in a hybrid course gain equivalent content knowledge as those taking a similar traditional lecture–lab course. Fortuitously, we were able to test this hypothesis because one of the instructors (CC) was also teaching a traditional large enrollment course in physical geology (G100) and the ElEd major enrollment in that course (35 of 477 students) provided a natural comparison group with our online cohort.

In the online course students took four proctored online exams throughout the semester. The exams consisted of 30 multiple choice questions randomly selected by Blackboard from the same pool of questions used for the 10-item weekly quizzes. Questions addressed only material covered in the four weeks preceding the exam and students had four days available to take the 1-hour exam. Knowledge surveys (Nuhfer and Knipp, 2003; Wirth and Perkins, 2005) were created to allow students to self-assess their level of confidence in the material covered by each exam and to plan their preparation accordingly. However, only between 60% (third survey) and 80% (first survey) of the students took advantage of this opportunity. Students could take the test twice but not on the same day; however, the likelihood of receiving the same 30 questions from a pool of 100+ questions was slim. The better of the two attempts counted towards their grade. Not all students planned their schedule so that they could try both attempts.

Students in this F2F course also took four multiple-choice exams, consisting of 30–40 questions that did not come from the same test bank used for the online course but from a test bank assembled by the instructor from multiple publisher-created test banks. However, the questions for

TABLE VI: Exam comparison, Semester 1.

	Exam 1			Exam 2			Exam 3			Exam 4		
	Online (%) $N = 32$	F2F ElEd (%) $N = 34$	F2F All (%) $N = 477$	Online (%) $N = 33$	F2F ElEd (%) $N = 33$	F2F All (%) $N = 477$	Online (%) $N = 32$	F2F ElEd (%) $N = 31$	F2F All (%) $N = 477$	Online (%) $N = 33$	F2F ElEd (%) $N = 31$	F2F All (%) $N = 477$
Mean	61.88	60.73	68.85	62.93	53.31	59.7	62.50	60.61	71.43	66.06	63.06	70.85
SD	9.69	13.15	15.67	12.44	13.86	14.36	11.58	13.19	13.23	12.18	12.19	13.3
Median	61.67	57.35		63.33	53.13		63.33	57.58		66.67	65.00	
t-test	0.69			0.004			0.55			0.33		

both courses were selected by the same instructor and were considered comparable. Table VI compares the average exam scores of ElEd majors in the two courses with the overall average in the F2F course, and Fig. 3 compares the exam score distributions of the ElEd majors in G100 and the online course (G106X). In a two-tailed unpaired *t*-test there is no statistically significant difference for the scores of elementary education students in the first ($p = 0.69$), third ($p = 0.55$), and fourth ($p = 0.33$) exams. There is a statistically significant difference in the second exam ($p = 0.004$) with the online students scoring on average 9.62% higher than the F2F students, but we believe this simply reflects that the F2F Exam 2 was the one exam that covered a much wider range of topics than its online counterpart. Exam 2 for the online class included weathering, landslides, volcanoes, and plate tectonics; in the F2F class it covered these topics plus igneous and sedimentary rocks, earthquakes, and the water cycle.

In all four exams in the F2F course, the average of the ElEd majors is significantly worse than the overall class average. In Exam 2 the average score of the online students is 3.2% higher than the average of the F2F course.

We also wanted to investigate whether our first-year students (Y1), who made up about 60% of the class, had

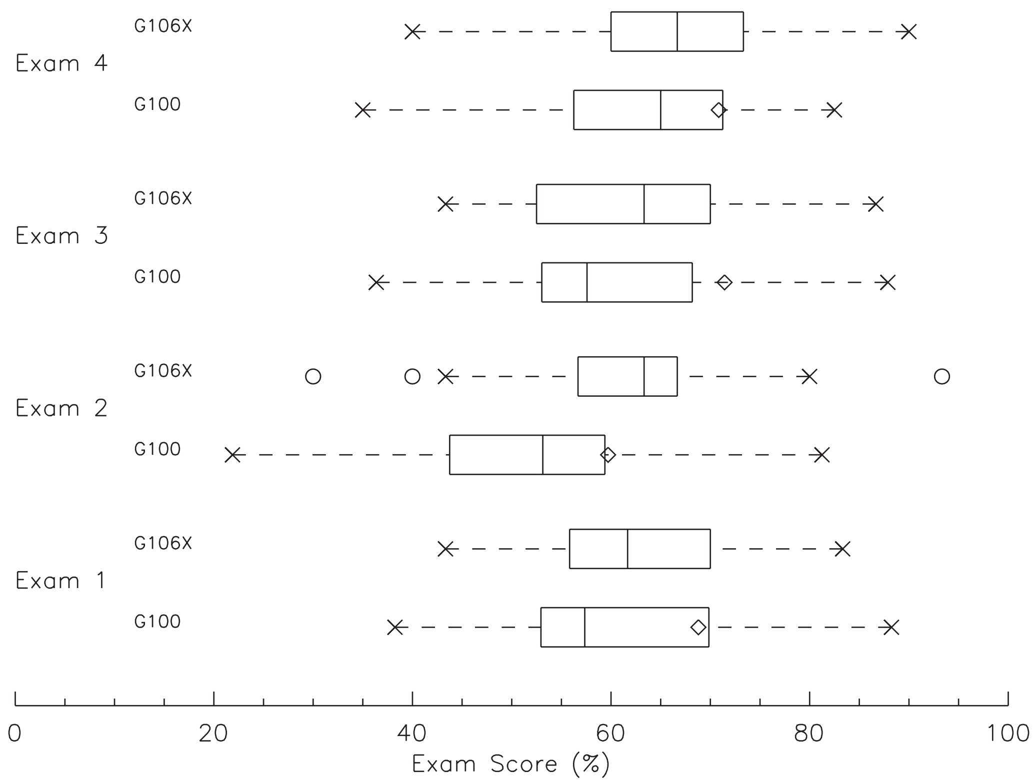

FIGURE 3: Online and F2F exam score distributions for Semester 1 (F11). There is no significant difference between the exam score distributions of ElEd majors in the online course (G106X) and a traditional, large-enrollment F2F course (G100) for three of the exams (1, 3, and 4). In Exam 2 the G100 scores are lower, but we believe this reflects a mismatch in the level of difficulty of the two exams. For reference, the average score for all G100 students is plotted as a diamond. In our box-and-whisker plots, the boxes span the interquartile range (IQR) between the first and third quartiles (Q1 and Q3), and the vertical line indicates the median score. A cross indicates the lowest/highest score within 1.5 IQR of Q1/Q3. Scores beyond 1.5 IQR of Q1 or Q3 are shown as open circles.

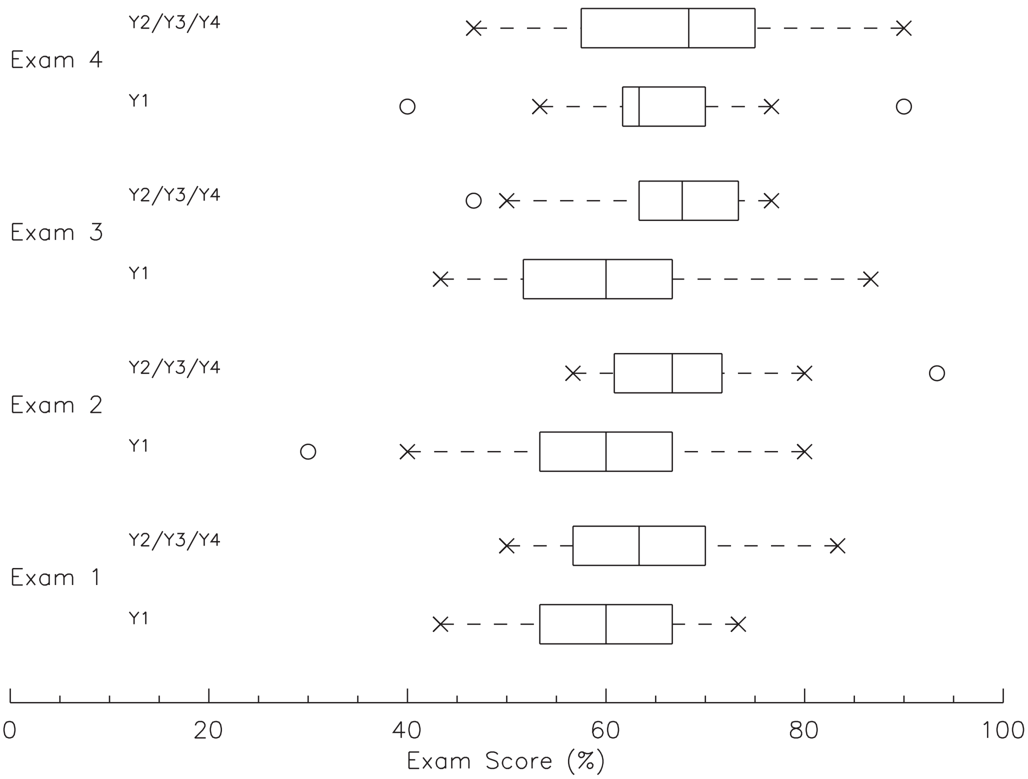

FIGURE 4: Exam score and year of study for Semester 1 (F11). The exam scores for first-year students (Y1) are compared with those of more senior students (Y2/Y3/Y4). While the median score for the Y2/Y3/Y4 cohort is always larger than that of the first-year students, there are no statistically significant differences between the exam performance of the two groups.

more difficulties with the online course compared with more senior students (Y2/Y3/Y4). The hypotheses was that the latter would either have more well developed study and time management skills and/or would have experience in taking online courses and be more comfortable with the medium. Figure 4 shows the exam score distributions for these two groups. In each case the median score for the Y2/Y3/Y4 group is higher than the Y1 group, but there is no statistically significant difference between the overall distributions. The closest case is in Exam 2 where the *t*-statistic comparing Y1 and Y2/Y3/Y4 is −2.05 (0.05 significance), but if the two outliers in the distributions are ignored the *t*-statistic is only −1.40 (0.17 significance).

Challenges and Lessons Learned

To assess course progress, we solicited feedback from the students through an anonymous online survey in the middle of the semester. The response rate was almost 100% even though participation in the online survey was voluntary.

Some of the issues identified by the survey were related to the hybrid course format. Students were confused about the relationship between material covered online and in the lab and perceived that there could have been a better synchronization between them. During the course design, the design team discussed the issue of drawing a clear link between the lab and the online course. We decided to treat the online course and the lab as separate events in our course design due to time and resource constraints. However, we did not anticipate the strong link that students would form between the online class and the lab component. Students were also uncertain about the online instructors' role versus the role of the lab's teaching assistant, and would have liked regular F2F meetings with the instructors during lab time.

The other issues were related to the specific cohort of students enrolled in this course. Many of them had difficulty in keeping up with the weekly schedule and deadlines, and/or had problems with technology. Blackboard would occasionally malfunction and kick a student out of an assignment, or the Internet connection would fail during a quiz and the assignment needed to be reset by the instructor. These occasional technical issues and the perception that the course required too much time led to frustration towards the course. We speculate that most of these issues were due to the fact that the majority of students (about 60%) were freshmen just entering college and that they did not have an alternative to this hybrid course, i.e., they had not chosen to take a course that was delivered in part online. We also found that several students, in spite of being "Digital Natives" (Prensky, 2001), were not as comfortable using technology for their learning as we might have expected, confirming what has been shown elsewhere (e.g., Kvavik, 2005; Bennett et al., 2008; Kennedy et al., 2008).

Our experience also confirmed studies (e.g., Feistritzer and Boyer, 1983; Bleicher, 2009) that show many ElEd

TABLE VII: Challenges and related course modifications.

Challenge	Modification
Students perceive a lack of connection between lab and online topics.	Shuffled order of lab topics to better match online timeline. TA explicitly points out connections to online material during lab.
Students unsure of role of TA and supervising faculty.	Supervising faculty makes brief weekly lab appearances.
Students had trouble keeping up with the weekly workload.	Made some work (experiments and self-assessment) optional and reduced the number of weekly online activities.
Students felt isolated from supervising faculty.	Faculty make brief weekly lab appearances.
Occasional technical problems with Blackboard.	There has been ISU-wide improvement with Blackboard as IT adjusted to increased usage.
Students were not comfortable with technology and/or web interface.	Changes made to web layout. Some Geotours due early in semester to catch technical issues early.
Students felt too much material was being covered.	No modification to content. Discuss this topic with students at initial course meetings and set expectations of high workload. Highlight how selection of topics meets new State requirements.
Students thought course was unrelated to career goals.	Include readings to explicitly address this issue emphasizing importance of introducing science in K–5 plus adding important skill to set them apart in crowded K–5 job market.

majors are not intrinsically motivated to learn science content. Therefore, our students perceived this course and its content as unnecessary for their future career as teachers, and said so in the course survey. However, qualitative evaluation of the content of the questions and answers in the discussion and the students' e-fieldbooks suggests that students were sufficiently engaged in the course. Although many students were struggling with truly reflective thinking, in which evidence is examined from multiple perspectives and is supported by meaningful conclusions, several individuals were modeling reflecting processes by bringing an array of web resources to the attention of their peers and comparing the material in these sources with what was being presented in the course and expressed by their fellow students. E-fieldbooks offered further glimpses into the learning process of several individuals who were surprised with vast gaps of their knowledge and noted that "doing science" stimulated re-evaluation of their own thinking. To emphasize this point, a number of students attached images of their experiments.

As shown in the previous section, their exam average is quite consistent with the results of other ElEd majors enrolled in a traditional F2F introductory science course, suggesting that the online format does not negatively affect their learning. However, it is significantly lower than the F2F course average, suggesting that they do in fact struggle with science content more than other student groups.

Some of the students felt that the course covered too much material. We believe that this was mostly due to a false perception that since the content was drawn from three different three-credit courses, it must be equivalent in workload to nine credits. The difficulty some students had in keeping up with the weekly timeline certainly only reinforced this idea.

In spite of our intensive preparation, we did not fully comprehend the challenges of teaching a hybrid science course to this specific group of students until we actually did it. Our focus on student engagement meant that the course was academically challenging, and involved multiple opportunities for the students to test their knowledge and be actively involved in the content. Students were asked to develop questions and answers for the discussion each week and to work on experiments while documenting their experience in their e-fieldbook. This resulted in a workload that was higher than what students expected from an online course. In addition, the online course that we designed requires self-discipline, self-motivation, and good time management—all skills that few students develop before entering college. Students who choose an online course format rather than a F2F course are probably aware of its challenges, are more comfortable with learning technology, and prefer the self-paced learning afforded by an online format. Our students were not given that choice.

A learning-style survey completed by the students in the first week of classes showed that the vast majority of them are classified as "concrete sequential" thinkers who process information in a linear, ordered way. Concrete sequential thinkers do not like to experiment and get easily frustrated when things do not work as predicted (Gregorc, 1984).

To address the challenges encountered in the first semester, we adjusted the course for the second semester (see Table VII). We reduced the types of required assignments, making the self-assessment optional and the experiments worth extra credit. We added the option of a second attempt to the weekly graded quizzes. We have made some changes to the layout of the course in Blackboard to improve its ease-of-use by adding dates to the list of modules and moving the introductory material to the front page. We have also added brief weekly appearances by one of the instructors at the beginning of each lab to answer questions and encourage students to work regularly on the online material. Geotours are due at two points during the semester thus acting as milestones that encourage students to develop the required Google Earth skills early in the semester rather than in a last-minute panic. The result is a more balanced workload for students and an increased

TABLE VIII: Online exam results, Semester 2.

	Exam 1	Exam 2	Exam 3	Exam 4
N	29	29	28	27
Mean	62.87	70.57	73.10	77.16
SD	11.91	15.28	15.69	15.35
Median	63.33	73.33	75.00	83.33
t-test (vs. Online, Semester 1)	0.72	0.034	0.004	0.003
t-test (vs. F2F ElEd, Semester 1)	0.50	0.00002	0.002	0.0003

overall rating of the course in anonymous end-of-semester course evaluations.

In summary, we encourage instructors developing a hybrid or fully online course for ElEd majors to build checks in the course that promote the development of time management skills. If the course is hybrid in nature, then the instructor should take full advantage of any F2F meeting times to address motivational issues explicitly, and to touch base with the students regularly.

COURSE TESTING—SEMESTER 2

With these changes in place, the course was offered again to 29 students in spring semester 2012 (S12). To assess the impact of the changes on student learning as determined from the scores of the four proctored exams, we compared the S12 scores with the F11 online and F2F scores (see Table VIII, Figs. 5 and 6). The average score for Exam 1 is essentially indistinguishable from of the scores obtained in F11, but the scores of Exams 2, 3, and 4 are significantly higher. As before, we found that there was no difference in the performance of freshmen versus older students (Fig. 7), suggesting that the increased averages were due to the improvement of students' study skills and/or appropriate test-taking strategies. After the first exam the instructors made a concerted effort to remind students of such things as: not rushing through the exams, using the available self-assessments and knowledge surveys, budgeting time so they can take advantage of taking the exams twice, and using the quiz results to help prepare for the exams. While all of these items may be considered obvious, it appears that an explicit

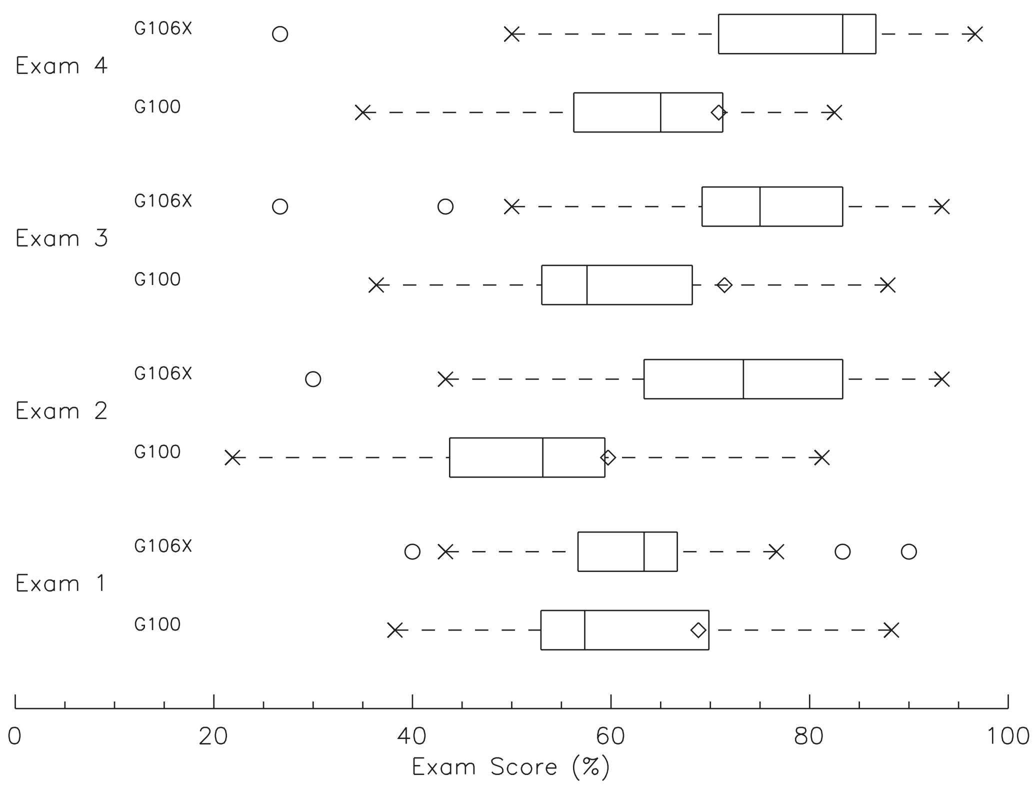

FIGURE 5: Online and F2F exam score distributions for Semester 2 (S12). The plots compare the exam score distributions for ElEd majors in the revised version of the online course (G106X) against a traditional large-enrollment F2F course (G100). Note the similarity of Exam 1 to the Semester 1 results (see Fig. 3) and the striking changes in Exams 2, 3, and 4.

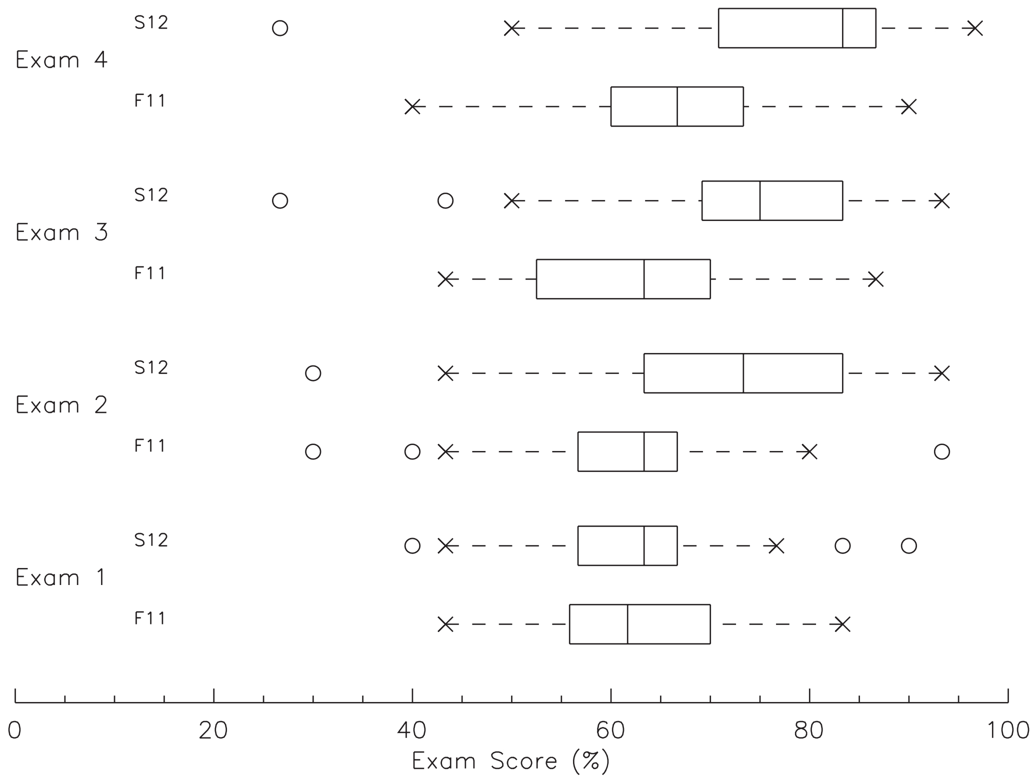

FIGURE 6: Comparison of online exam performance. The plots compare the exam score distributions of the online classes in the Semester 1 (F11) and Semester 2 (S12) versions of the course. Note the statistically significant improvement in the performance of the S12 students in exams 2, 3, and 4.

reminder of these basic skills and strategies proved helpful for many of our students.

The midsemester and end-of-semester feedback suggests that the adjusted workload was much more manageable, which was possibly reflected in a better attitude of the students towards the class that resulted in higher exam averages. The average number of hours per week spent working on the course that the students declared in the S12 evaluations was 2.5; in F11, this average was 4.36 hours. However, the apparent disconnect between lab and online course was still seen as an issue by a few of the students, and there was still some confusion regarding the course's aims (science content versus science teaching methodology). Some students did not like that the course was online and thought that it would be easier to understand or retain material in a F2F lecture.

CONCLUSIONS

We examined two hypotheses related to the creation of a new E&SS hybrid course for ElEd majors at ISU. First, we found that a hybrid course did have a lower in-semester workload for supervising faculty compared to a similar F2F introductory science course. Second, we found there was no significant difference between the content knowledge acquired by ElEd students in the hybrid course compared with a similar group of students in a traditional F2F introductory geology course. This confirms earlier comparative studies of online versus traditional courses (e.g., Lim et al., 2007), but not the more recent trend showing better performance of online students (U.S. Department of Education, 2010).

In the second semester, the averages for three of the four exams were significantly higher than in the first semester after some workload adjustments based on students' feedback. We also found no difference in performance between freshmen and nonfreshmen in either semester, suggesting that better study skills and/or the development of more appropriate test-taking strategies can explain the improvement in test scores. From our experience we conclude that a hybrid course model does provide an effective means of presenting E&SS content when instructional resources are constrained making traditional F2F instruction impractical.

The target student cohort for this course, first year ElEd majors, present some interesting challenges for instructors and course designers, some of which are not unique to online/hybrid courses. We found that our students, at all stages of their studies, were not used to the self-guided instruction required for success in online courses and overall were not as comfortable using web-based technology for instruction as we expected. Based on our second semester results, explicit reminders of basic time management and study strategies early in the course appear to greatly benefit this cohort of students.

Finally, motivation for learning science content was also low among this group of students. We think this is the root cause of our biggest remaining challenge, namely that

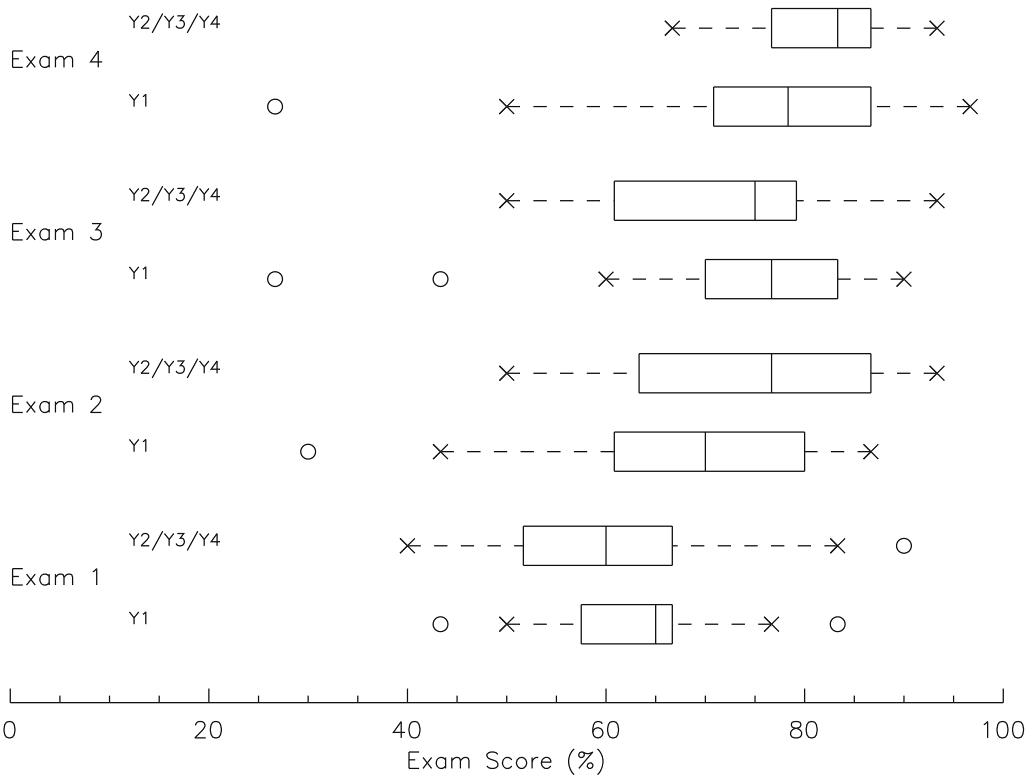

FIGURE 7: Exam score and year of study for Semester 2 (S12). The exam scores for first-year students (Y1) are compared with those of more senior students (Y2/Y3/Y4). There are no statistically significant differences between the exam performance of the two groups.

students thought the material was of little use to their chosen career. In the future, we plan to augment our current readings explicitly addressing this issue with specific examples of good elementary science teachers, such as recent Presidential Award for Excellence in Mathematics and Science Teaching (PAEMST) winners working in Iowa, with the ultimate goal of demonstrating that having a sound understanding of science content fundamentals will allow them to become better elementary school (science) teachers.

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