Knowledge Surveys: An Indispensable Course Design and Assessment Tool

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Abstract

Knowledge surveys are an indispensable tool for course design, learning, and assessment. The surveys consist of questions that cover the full breadth of content and levels of inquiry in a course. Students complete knowledge surveys at the beginning, middle, and end of a course by indicating their perceived ability to answer questions about course content. The process of developing a knowledge survey helps the instructor clarify and organize the course objectives. During the semester the survey serves as an outline of the course and learning objectives and as a tool for helping students develop self-assessment skills. Pre-course survey data can be used to guide course content, and mid- and post-course surveys provide information about learning gains. Comparison of knowledge survey responses, examination results, and final course grades suggests that the surveys provide meaningful measures of learning gains.

Introduction

Recent changes in education have had significant impacts on the focus of learning, the nature of classrooms, and the roles of teachers and students. There is greater emphasis on developing skills and attitudes needed for life-long learning. Active and collaborative learning is used to complement lectures in many classrooms. Faculty roles are shifting from being primarily "instructors" to "facilitators of learning." Students are encouraged to take responsibility and play a greater role in their learning. Concomitant with these changes has been the recognition of the importance of assessment, both in curriculum design and in learning. Traditional assessment tools, including quizzes and exams, are largely summative and tend to emphasize a narrow portion of the learning continuum. In-class exams generally cover only a narrow range of course content and are not well suited for assessing higher-level understanding and skills. There is an real need for new tools that: (1) can be used to provide formative assessments of student understanding; (2) provide more comprehensive assessment of student learning; (3) can be readily employed by students to monitor their own learning and to develop skills of self-assessment; and (4) can be used by faculty to understand the effects of curricular changes and innovations.

Both of us use inquiry-based methods in our courses, where students work cooperatively in teams to solve problems and "discover" understanding. Lectures are largely prescriptive and are used in response to student needs for information or understanding. Students learn concepts and skills in greater depth, but the time-intensive nature of the inquiry-based approach often means that less content is covered in the classroom; some content comes solely from textbooks and readings. As a result, the responsibility of "first uncovering" course content is largely shifted to the student. Although some students may be initially uncomfortable with this new approach and responsibility, we have found that, with just a little explanation and guidance, they "thrive" in it. Knowledge surveys have played a critical role in facilitating our transitions to active learning. However, because knowledge surveys are so ideal for supporting course design, student learning,

and assessment, we consider them an essential tool for all courses. In this paper we describe the utility of knowledge surveys, and present some of the results obtained in our classrooms.

Knowledge Surveys

Knowledge surveys were first described by Nuhfer (1993) and were further developed by Nuhfer (1996), Knipp (2001), and Nuhfer and Knipp (2003). Knowledge surveys consist of a large number of questions that cover the full content in a course. The questions are designed to cover different levels within the cognitive domain (Bloom, 1956), ranging from knowledge to comprehension, application, analysis, synthesis, and evaluation (Table 1). When completing the knowledge surveys, students do not answer the questions. Instead, they indicate their perceived ability to answer the questions using a three-part scale (e.g., Table 2). Knowledge surveys are typically conducted at the beginning and end of a course and are not graded (Nuhfer, 1996; Nuhfer and Knipp, 2003). The surveys can be carried out using traditional computer answer sheets, but web-based courseware and electronic testing tools are more efficient. If surveys are administered electronically, students can complete them out-of-class and the survey results are more easily analyzed and interpreted using spreadsheet software. Researchers at University of North Dakota and Georgia Southern University are currently developing dedicated software for administering knowledge surveys and analyzing survey results (*URL's*: UND, *no date*; GSU, *no date*).

Table 1. Example questions from the knowledge survey in the Macalester College 2005 Petrology course. Questions are classified according to Bloom's (1956) taxonomy.

Question	Bloom Level
According to Bloom, what are the different levels of thinking?	1 (knowledge)
Explain how the "wiring in the brain" can change with age and use.	2 (comprehension)
Use the elements of critical thinking to analyze a sample of writing.	3 (application)
Compare the different levels of reasoning according to Bloom's taxonomy.	4 (analysis)
Construct a diagram that synthesizes Bloom's levels of understanding with Fink's 2003 model of significant learning	5 (synthesis)
Using the list of "qualities that distinguish outstanding students," appraise your own study and learning habits and suggest a course of action.	6 (evaluation)

Table 2. Responses available to students for answering questions on knowledge survey.

I do not understand the question, I am not familiar with the terminology, or I am not confident that I can answer the question well enough for grading purposes at this time
I understand the question and a) I am confident that I could answer at least 50% of it correctly, or b) I know precisely were to find the necessary information and could provide an answer for grading in less than 20 minutes
I am confident that I can answer the question sufficiently well-enough for grading at this time

At Macalester College, students complete knowledge surveys (230-400 questions) at the beginning of the Exploring the Solar System (Geol-102), Dynamic Earth and Global Change (Geol-150), Mineralogy (Geol-250), and Petrology (Geol-302) courses. The knowledge surveys are administered using Moodle, an open-source learning management system. Students complete additional knowledge surveys, consisting of a smaller number of questions, just prior to each exam (approximately each third of the course). Students also benefit from using the knowledge survey as a study guide because some exam questions come directly from the knowledge survey. A final comprehensive knowledge survey consisting of all of the questions is

administered again at the end of each course. Knowledge surveys are used in a similar way at the University of North Dakota. Students complete surveys in several sections of Introduction to Geology (Geo 101), Mineralogy (Geo 318) and Petrology (Geol 320). Knowledge surveys for each of these classes contain about 200 questions.

The ease with which knowledge surveys can be constructed, administered, completed, and analyzed makes it possible to assess the content of a course in considerable detail and depth (Nuhfer, 1993; Nuhfer and Knipp, 2003). Analysis of knowledge survey responses yields a wealth of formative and summative information for both students and teachers.

Knowledge Surveys as a Course Design Tool

We are reminded by Nuhfer and Knipp (2003) that teacher preparation and course organization are the most important variables that correlate with student learning in a course (e.g., Feldman, 1998). To the extent that preparation of a knowledge survey helps clarify and organize course objectives (Nuhfer, 2004a), it also has the potential to improve student learning. Although we initially adopted knowledge surveys as a way to evaluate student learning, there is, perhaps, an even more significant benefit. In the process of creating a knowledge survey, the instructor ends up analyzing the content and learning objectives of a course. Though this may not be obvious before implementing knowledge surveys, we have both found it to have great impact.

Questions for a knowledge survey can initially come from previous quizzes and exams, laboratory exercises, homework problems, textbooks and other readings. The process of selecting questions is valuable in itself because it helps the instructor identify the most important content and enduring concepts of a course (e.g., Wiggins and McTighe, 2001), and weed out those of superficial or ancillary importance. The process of classifying questions using Bloom's taxonomy is also very revealing. We found that some of our past exams (and instruction) may have put an overemphasis on lower levels of understanding (knowledge, comprehension, application). Consequently, we have modified our classroom activities, and prepare exams and other assessments that have a balancing emphasis on higher levels of understanding (analysis, synthesis, and evaluation). Finally, results of pre-course surveys provide us with information about knowledge and understanding of students as they enter a course. If prerequisite knowledge is poorly developed, or if some introductory content has already been mastered, we modify course activities accordingly.

Benefits to the Student

The knowledge survey serves several purposes for students (Nuhfer, 1996; Nuhfer and Knipp, 2003): (1) it provides full disclosure of the course content and learning objectives to the students, (2) it serves as a learning guide throughout the course, (3) it makes student learning more "visible" throughout the course, and (4) it serves as a tool for developing self-assessment skills. Together, these contributions provide students with more comfort and a greater sense of control over their learning.

Knowledge surveys provide students with explicit statements of course objectives and goals. Students sometimes tend to focus on learning facts, but the surveys clarify higher-order learning objectives. The surveys illustrate the role and importance of the different levels of understanding required for mastery of the course.

Students can use knowledge surveys as a learning guide throughout a course (Nuhfer and Knipp, 2003). Access to the structure and objectives of a course helps them focus their learning. This can be particularly important in courses that make greater use of alternative pedagogies. For example, in courses that emphasize active learning there is a de-emphasis on lecture and students have a greater responsibility in the "first uncovering" of course content. Students sometimes find this new responsibility daunting and are unsure how to focus their learning. The knowledge survey provides a detailed reading and study guide by outlining the important content and required levels of understanding. Students can review survey questions to identify the important facts and concepts before completing a reading assignment. After reading the assignment they can review the survey questions to self-assess their understanding of those facts and concepts. If students identify gaps in their understanding after this review, they have clear knowledge of the nature of those 'gaps' as they re-study material or seek assistance from other students or instructors.

After completing a unit of a course, students can use the relevant parts of a knowledge survey to assess their preparation for an exam or quiz. Students can use the knowledge survey as an informal study guide to prepare for an exam. After studying, but prior to taking a written examination, they can respond to survey questions in a more formal setting (e.g., online or on paper). If after completing the survey they feel prepared, they can enter the exam feeling confident in their preparation. Alternatively, if in the process of completing the formal knowledge survey they identify gaps in their understanding, they can complete additional preparation before an exam.

Many instructors, when they first learn of knowledge surveys, express concern about their reliability as measures of student understanding. Examples of knowledge survey results used in this manner are illustrated in Figures 1 and 2. In both figures, the results of pre-course and pre-exam (completed after studying, but prior to exam) survey responses are compared with exam scores. Several interesting relationships can be inferred from these plots. Pre-exam survey responses are generally well correlated ($r > 0.70$) with exam scores. Prior to taking the first exam, two students (Nos. 12 and 13) indicated relatively low confidence in their understanding; their performance on the examination supported this perception. Both of these students scored similarly on the second mid-term exam and the pre-exam survey that preceded it (Figure 2). A third student (No. 9) also indicated low confidence prior to the first exam, but then completed a very strong exam. In this case, the differing results could be interpreted to indicate low self-confidence, poor self-assessment skills, or the completion of additional pre-exam studying after gaps in understanding were revealed by the knowledge survey. Note that this student's pre-exam survey before the second exam (Figure 2) more accurately reflected his mastery of the material.

Learning gains can be evaluated both formally and informally using knowledge surveys (Nuhfer and Knipp, 2003). Consultation with a knowledge survey throughout a course helps students 'see' their progress in learning content and understanding concepts. A more formal assessment of learning gains can be conducted using plots such as those shown in Figures 1 and 2. In these plots learning gains can be estimated from the difference in the pre-course and pre-exam survey results (Figures 1 and 2). These plots can be cut so that each slice contains data from only one student. These data can then be distributed to students and discussed in class, or used for one-on-one conferences.

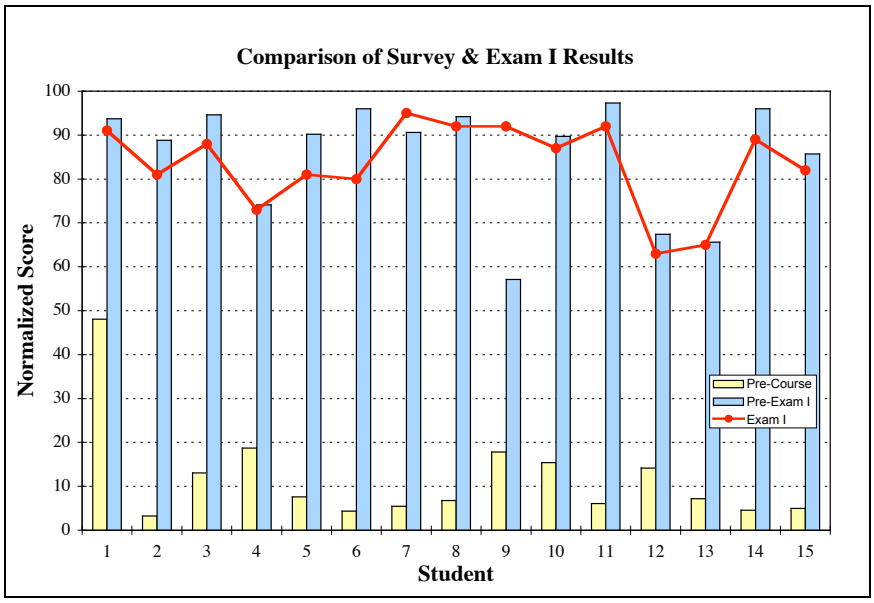

Figure 1. Histogram plot of pre-course and pre-exam knowledge survey and first mid-term exam results for students (n = 15) in the Macalester College Dynamic Earth and Global Change course. Survey results are normalized to 100 for comparison with exam results. For most students, the pre-exam survey results correlate well (r = 0.90 for all students excluding #9) with exam score. Students 12 and 13 indicated a lack of preparation on the pre-exam I survey, and their exam scores reflect lower levels of understanding. Student 9 indicated low confidence on the pre-exam I survey, but completed a very strong exam suggesting lack of self confidence, poor self-assessment skills, or additional pre-exam preparation after taking the survey.

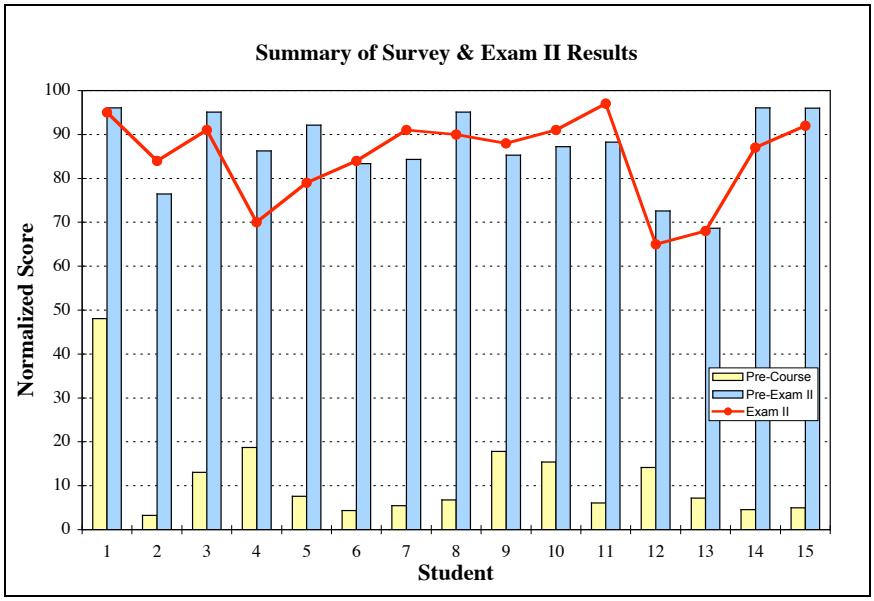

Figure 2. Histogram plot of pre-course and pre-exam knowledge survey and second midterm exam results for students (n = 15) in the Macalester College Dynamic Earth and Global Change course. For most students, pre-exam II knowledge survey results correlate well (r = 0.70) with exam score. As in the first exam, students 12 and 13 indicated a lack of confidence on the knowledge survey and their exam scores reflect lower levels of understanding. Note that student 9 had a more realistic assessment of content mastery in the pre-exam survey before the second exam (compare with Figure 1).

Finally, knowledge surveys can be used to help students develop their self-assessment skills (Nuhfer and Knipp, 2003). Ideally, if we want our students to be life-long learners and independent thinkers, they must have the skills to assess their own understanding (e.g., Fink, 2003). By comparing the results of pre-exam surveys with exam scores students have access to direct evidence on their self-assessment skills. This comparison is facilitated if some of the same questions appear in both assessment tools. If students consistently over- or under-estimate their level of understanding, a comparison of survey and exam results (e.g., Figures 1 and 2) can be used as a starting point to help them develop strategies for improving self-assessment skills.

Benefits to the Instructor

Knowledge surveys not only benefit students, they also provide essential information to the instructor, both during the course and for assessing student learning, pedagogical methods, and course design. Pre-course knowledge surveys provide a means of knowing the background and preparation of students in a course. If students bring to the course more or less background knowledge than was anticipated, knowledge surveys provide a mechanism for discovering these discrepancies. Knowledge survey results can also be used to assess student backgrounds when forming groups for collaborative activities and they serve as a reminder to faculty to cover key concepts throughout the course.

Assessment of student learning poses a complex and multidimensional problem. Traditional assessment tools include exams, quizzes, problem-sets, papers, and projects. In-class exams are generally not well suited for measuring learning, especially when assessing higher-level learning. Whereas exams generally measure learning over a narrow portion of course content and are subject to problems of reliability (e.g., Nuhfer, 2004b), knowledge surveys measure learning across a broader spectrum (all) of learning objectives in a course. Furthermore, the constraints of in-class exams often limit the number of questions that address higher levels of understanding. In contrast, the design of knowledge surveys, in which students do not answer the question but respond with their confidence to answer a question, facilitates coverage of a larger number of questions that cover higher-level understanding. Furthermore, knowledge surveys can be administered frequently throughout a course and outside the regular classroom meeting time. If comprehensive knowledge surveys are completed at the beginning and end of a course, the results provide a measure of content mastery by individual students and the class as a whole.

Determining whether knowledge surveys are reliable tools for assessing student learning is hampered by the lack of a control, or other suitable standard for comparison. Exams, because of their brevity, are at best "summative snapshots." They consist of relatively few questions, cover narrow ranges of content and cognitive levels of inquiry, and are generally quite stressful. Student evaluations of courses do correlate with learning, but the correlation is relatively low ($r = 0.43$; Cohen, 1981). Furthermore, the educational practices that produce the most learning in courses are ranked differently from those that produce the highest student ratings (Feldman, 1998). Final course grades in a course are perhaps the most multi-faceted indicators because they often reflect the weighted average of several different types of assessment, including problem sets, exams, projects, quizzes, and papers.

To examine the reliability of knowledge surveys as assessment tools we conducted a comparison of knowledge survey responses with exam scores and final grades in each of our classes. Here we present only comparisons of exam scores and knowledge survey responses from the Fall 2004 Dynamic Earth and Global Change course at Macalester College (Figure 3).

For this comparison we assumed that the exam was an accurate measure of learning, and we found that average class scores on exams are highly correlated with the average class responses on surveys (Figure 3). In other words, knowledge surveys provide reliable measures of learning when averaged across an entire class. As such, they can be used to assess the overall learning of a class.

On an individual basis, there is more scatter and only a moderate correlation between student exam scores and pre-exam knowledge survey responses ($r = 0.54$-0.68). However, if we do not use the entire battery of questions in the knowledge survey but consider only results for those questions used both in exams and the knowledge surveys, correlation is improved. Figure 4 compares average scores on questions that students encountered both in the surveys and in the exams; student self-assessments of understanding are generally realistic based on the small subset of questions. The fact that the results of knowledge surveys and exams are only moderately well correlated might be because exams are a poor measure of learning. Alternatively, the soft correlation might reflect variations in student abilities to self-assess their understanding and mastery of course content. Furthermore, if students use the knowledge surveys to their fullest potential by engaging in additional learning after completing the pre-exam surveys, then their level of understanding likely changes between the times they take the pre-exam surveys and the written exam.

We also investigated the reliability of knowledge survey results by comparing survey results with final grades in a course (Figure 5). As might be expected, the results of the pre-course survey are poorly correlated with final grade ($r = 0.14$). In contrast, the results of the pre-exam (I and II) and post-course surveys are more highly correlated with final grades in the course ($r = 0.53$, 0.79, and 0.72, respectively). It might also be expected that mid-course survey responses, especially those from early in the semester, would be less well correlated with the final grade. This is the case for the pre-exam survey for the first exam. One pre-exam survey result is noticeably distant from the 1:1 correlation line (the student described above who underestimated his knowledge in the pre-exam I survey in Figure 1). Again, the correlation between knowledge surveys and final grades is limited by the degree to which the learning objectives of the course are accurately reflected and assessed by those tools used to determine final grades.

In summary, as noted by Nuhfer (1996) and Nuhfer and Knipp (2003), knowledge surveys are ideally suited for assessing student learning. Various types of assessments can be conducted using an analysis such as is illustrated in Figure 6. Analysis of post-course survey data provides information about student mastery of course content and provides a tool for assessing the course in terms of the stated learning objectives. For example, students indicated relative low confidence to some questions (e.g., questions 117-171). Much of the content of these questions was covered in the textbook, but was not covered in lecture or by in-class projects. Furthermore, the third mid-term exam was cancelled to provide additional time for the final project. The decreased mastery of content in this portion of the course probably reflects the lack of a formal in-class assessment. Even without formal assessment of the content in this portion of the course, students had developed the motivation and skills for learning and self-assessment to learn the material. Comparisons of post-course results with pre-course and pre-exam survey results enable an analysis of learning gains and the "durability" of that learning. Alternatively, the results of pre- and post-course survey data can be sorted by Bloom level before (e.g., Figure 7). This type of analysis permits assessment of the student learning across the different levels of inquiry (Nuhfer and Knipp, 2003).

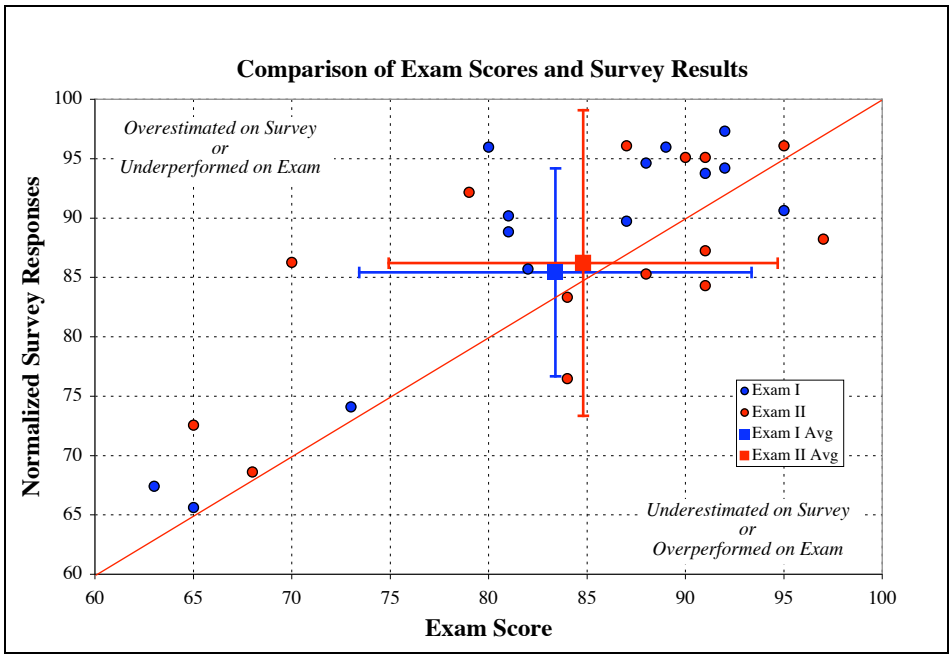

Figure 3. Plot of exam scores (midterm exams I and II) versus normalized survey results for students in the Dynamic Earth and Global Change course (circles). Also shown are class averages for each survey and exam (square symbols). Survey results are normalized to 100 for comparison. The diagonal line illustrates a hypothetical 1:1 correlation between exams and survey results. The good correlation between average exam scores and survey result illustrates the utility of knowledge surveys as assessment tools for learning. Individual exam and survey responses are less well correlated (r = 0.54-0.68).

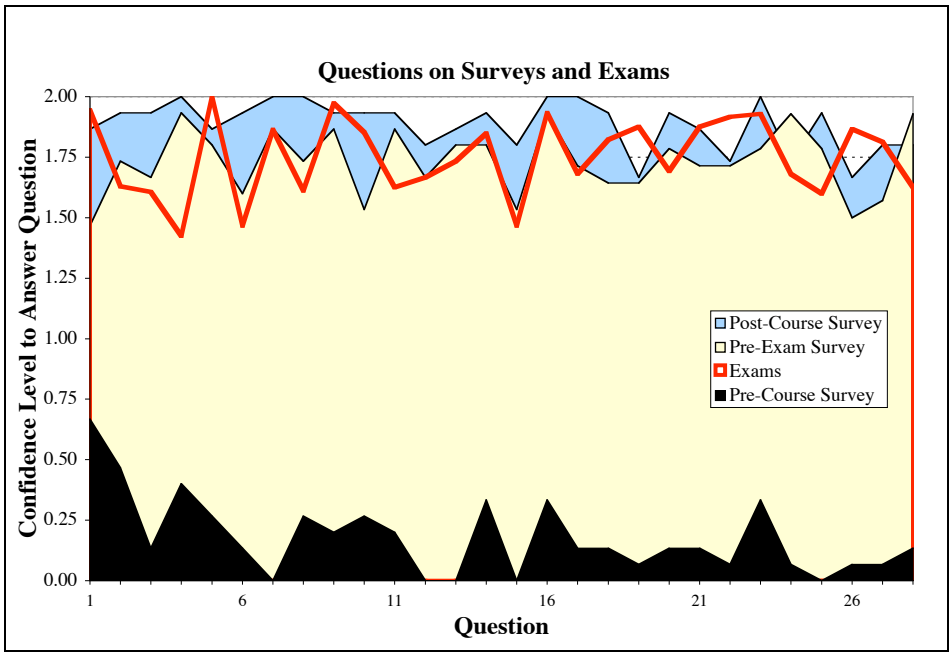

Figure 4. Histogram plot of average scores of questions used in exams (midterm exams I and II) compared with average responses to the same questions on knowledge surveys (pre-course, pre-exam, and post-course). Student confidence level (y-axis) to answer questions (arranged along x-axis) is indicated as 0 = no answer at this time, 1 = know at least 50% of the answer, or 2 = prepared to provide answer for grading.

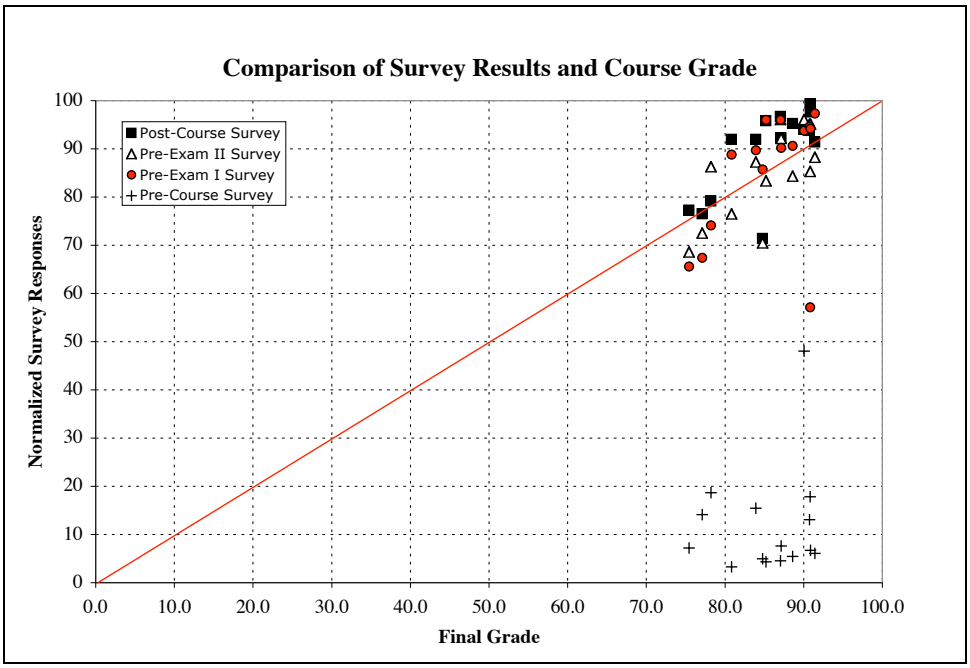

Figure 5. Plot of student final grades versus normalized knowledge survey scores. As might be expected, pre-course survey results do not correlate with final grade (r = 0.14). Pre-exam (I and II), and the post-course survey results have correlations coefficients (r) of 0.53, 0.79, and 0.72, respectively. A 1:1 correlation line (red) is illustrated for reference.

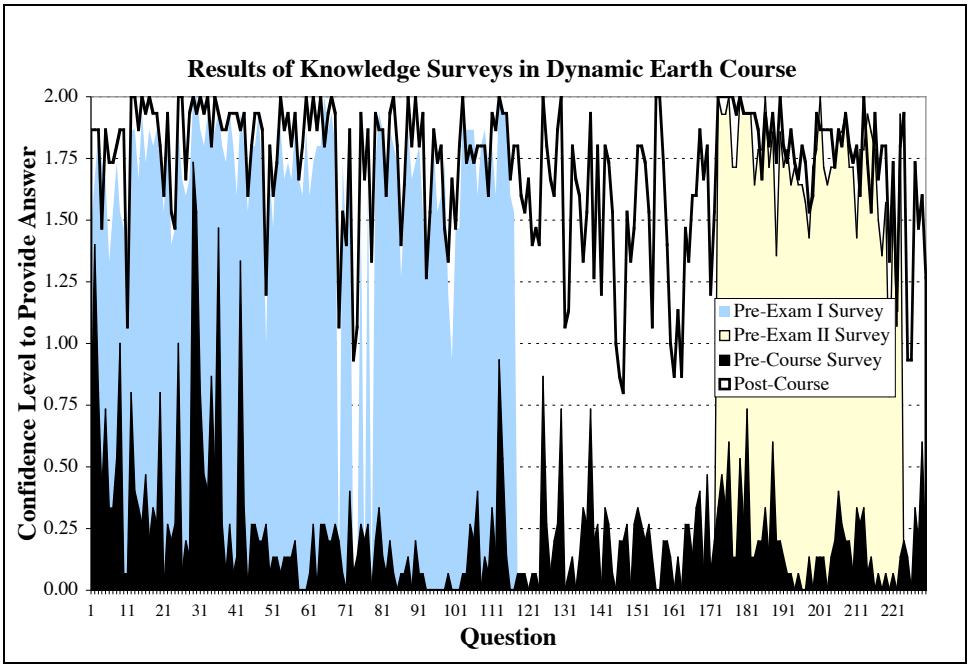

Figure 6. Comparison of average responses on pre-course, pre-exam (I and II), and post-course knowledge surveys. Axes are shown as in Figure 4. The third unit of the course was not covered by a traditional mid-term exam, so the learning in that part of the course was assessed with only the post-course survey.

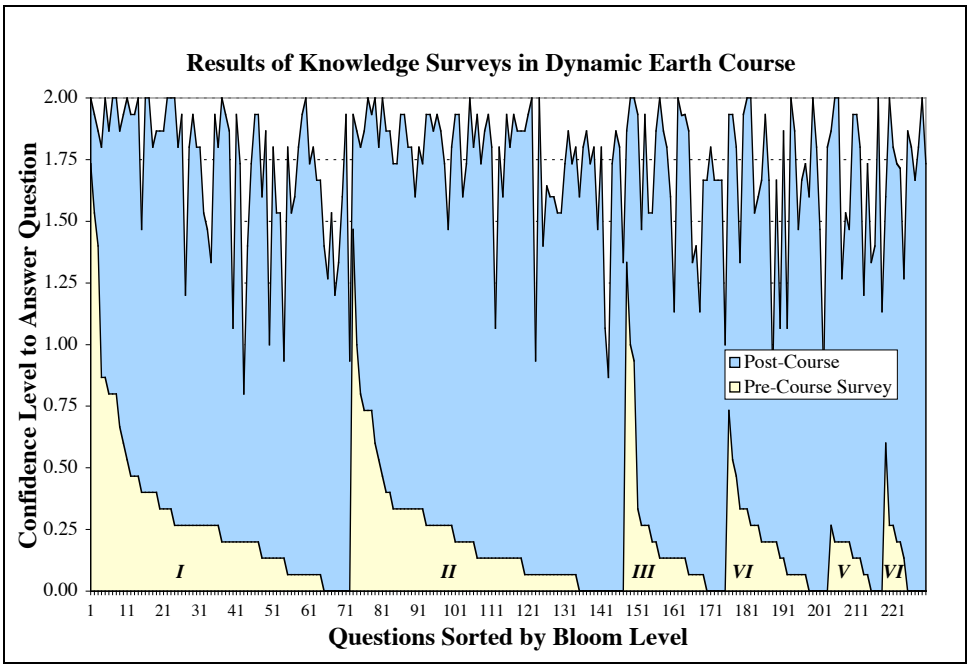

Figure 7. This diagram is similar to the one shown in Figure 6 except that the questions are sorted by Bloom level. Bloom levels are indicated in roman numerals along the base of the diagram. A plot of this format enables the instructor to assess the learning gains in the different levels of understanding in the course. Data in this plot indicate significant gains for questions representing all Bloom levels.

Knowledge surveys can also be used to evaluate the effectiveness of new pedagogies used in the classroom. In courses with greater emphasis on active learning, traditional assessment instruments may be inappropriate and instructors often need different ways of assessing learning. Exams from traditional lecture courses need to be modified significantly or abandoned altogether, making it difficult to compare learning gains in courses that use different pedagogies. Knowledge surveys help fill this need for new instruments of assessment. For example, during 2004 there were two different sections of the Dynamic Earth and Global Change course at Macalester College. Students in these two sections used the same textbook and laboratory manual, but were taught by different instructors. One course used a more traditional approach with three one-hour lectures and one two-hour lab per week. The second course had the same schedule, but used a non-traditional (problem-based learning) approach that included activities, discussions, and projects. The distinction between lecture and laboratory sessions was blurred; lecture constituted less than 25% of the course activity. Students in both courses completed the same final project and the same knowledge survey at the end of the semester. In most studies of non-traditional teaching practices, researchers find that innovative approaches to teaching work for most students most of the time. Comparison of knowledge survey responses from both courses indicates that student learning in the non-traditional course is comparable to, or slightly greater than, that of the traditional course (Figure 8). Some of the improvement may be due to instructor enthusiasm, but some is probably because traditional classrooms are not generally optimal for promoting student learning (see Perkins, 2004, and references therein). Although many instructors have concerns that students will have "gaps" in their understanding if they are not provided information through lectures, the data presented here strongly suggest that this is

not necessarily the case. Student learning in active-learning classrooms can be just as comprehensive and "deep" as in traditional classrooms.

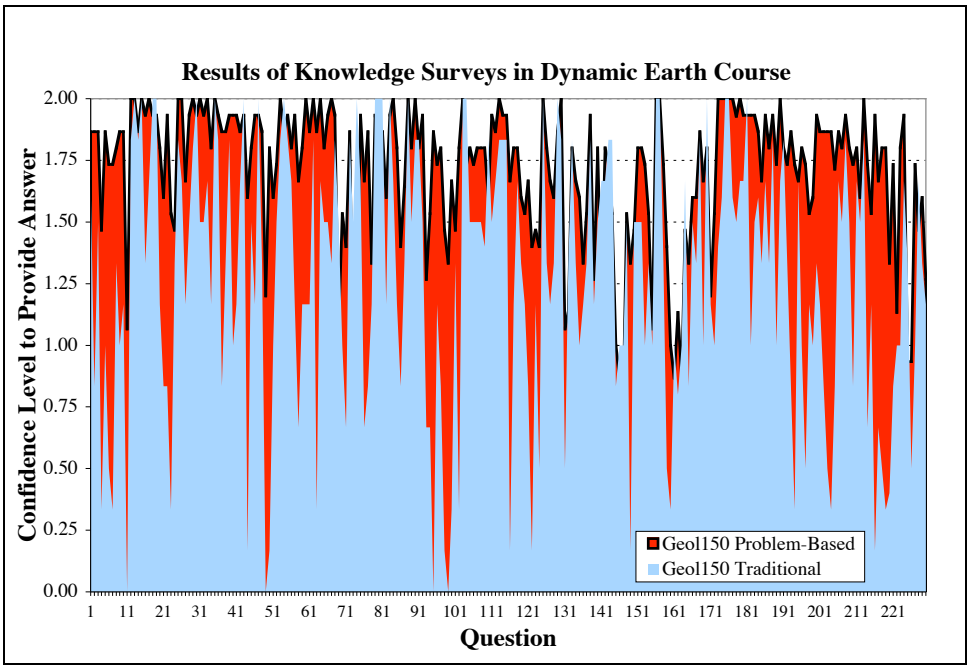

Figure 8. Comparison of post-course knowledge survey results from two different sections of the Dynamic Earth and Global Change course. One section (n = 15; 15 respondents) utilized problem-based and collaborative learning approaches, and the other section (n = 10; 6 respondents) utilized a traditional lecture-based approach. Each section of the course had its own instructor, but both sections used the same textbook and had the same instructor and exercises in laboratory sessions. The results suggest that student learning gains in the problem-based and collaborative learning course were similar to, or slightly greater than, those in the traditional lecture section.

Finally, knowledge surveys can be used by departments and other administrative units to assess curricula and programs. This spring the Geology Department at Macalester College will begin using knowledge surveys as part of its department assessment plan. Graduating seniors will complete a comprehensive knowledge survey that will be designed by all faculty in the department. The goal of this survey will be to determine the strengths and weaknesses of the curriculum. In future years, students will also complete the same knowledge survey when they declare a major in the geology. Preparation of this knowledge survey will undoubtedly result in greater focus and organization within our curriculum as well.

Summary

The knowledge survey is an indispensable tool for enhancing learning. The process of developing a knowledge survey facilitates the clarification and organization of course objectives. For the student, knowledge surveys provide an explicit guide to the content and objectives of a course. They can also be employed to as a formative assessment tool and can be used to help students develop self-assessment skills. Instructors can use knowledge survey results to assess learning gains, student understanding, and the effectiveness of new pedagogies. Knowledge survey results are variably correlated with other assessment tools (e.g., exams, course grades), but a quantitative analysis of surveys is limited by the lack of a suitable standard for comparison.

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