# An E-tool for Assessing Undergraduate Students' Learning of Surveying Concepts and Practices

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**Abstract.** We describe an innovative e-assessment tool for Surveying Education and report the results of a pilot study with a group of undergraduate students enrolled in the Building Construction Management Program at Purdue University. The e-assessment tool consists of two parts: a student's component and an instructor's component. The students' component is a Virtual Learning Environment that can be used by students to review surveying concepts and practices and get feedback on their understanding of the subject. The instructor's component is a summative assessment tool that measures the individual student's cognitive and practical abilities with high level of accuracy. Results of a pilot study with 31 students enrolled in an undergraduate surveying course show that students perceived the application as easy to use, very useful for reviewing class content, and effective at providing immediate and accurate feedback on their performance. A comparison between the grades obtained by manually grading the field exercise and the grades generated by the e-assessment tool showed a significant disagreement between the 2 sets of data, with the electronically generated grades being much lower. Analysis of the data recorded by the e-tool suggests that the deviation between the two sets of grades is due to the ability of the e-assessment tool to track the individual student's performance more accurately.

**Keywords:** E-assessment, Surveying, Games, Technological Issues in Education, E-content Management and Development, Virtual Universities.

## 1 Introduction

Surveying is "…the science and art of making all essential measurements to determine the relative position of points and/or physical and cultural details above, on, or beneath the surface of the Earth, and to depict them in a usable form, or to establish the position of points and/or details…" (American Congress on Surveying and Mapping - ACSM).

Surveying is a fundamental course in the Civil Engineering, Building Construction Management, Geomatics, Agriculture & Forestry, and Landscape Architecture curricula. One of the challenges of surveying education is the difficulty in assessing the individual student's cognitive and practical abilities. This difficulty is due to the fact that many surveying exercises are team efforts that require collaboration between

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at least two students. For instance, exercises that involve tape measurements, use of level to measure differential elevations, or theodolites to measure angles and distances are tasks that need to be completed by two or more students working closely together. It is challenging to evaluate the individual student's knowledge and performance, as it only takes one student to make a mistake in order for the team to get the wrong measurement. It is not uncommon for good students to get penalized for the mistake of another team-mate, or for mediocre students to get high grades because the other team members are knowledgeable and proficient at using the instruments.

The goal of the work reported in the paper was to enhance traditional surveying instruction methods with a unique approach: an effective e-assessment tool. The prototype program described in the paper contains 1 educational module (chaining) and it is a first step toward the development of a surveying e-assessment tool with 5 educational modules that will be integrated in introductory surveying courses. Students can use the e-tool to review concepts and practices and get formative feedback on their understanding of the subject; the instructor can use the program as a summative evaluation tool to generate a grade that truly reflects the student's performance. In the paper we report findings of a pilot study with 31 subjects. Evaluation results show that students reacted positively toward the program, were engaged with it and found the software to be very valuable. In addition, comments from instructors show that the prototype program was perceived as a very effective assessment tool for measuring the individual student level of competency in chaining.

The paper is organized as follows. In section 2 (Background) we define and discuss e-assessment and report examples of e-assessment tools for college-level learning. In section 3 (The Surveying E-Assessment Tool) we describe the design and implementation of the prototype program; in section 4 (Pilot study) we report a pilot study with a group of undergraduate students enrolled in the Building Construction Management program at Purdue University and analyze and discuss the findings. Conclusive remarks and future work are included in section 5 (Conclusion and Future Work).

## 2 Background

"The confluence of powerful technologies of computers and network connectivity (Beekman & Quinn, 2006) has brought new tools to college educators that can change the way they communicate and manage course assessments" (Skeele et al. 2008). The term e-Assessment is becoming widely used as a generic term to describe the use of computers within the assessment process. In general, e-assessment tools provide two forms of assessment: formative and summative. Formative assessment constitutes a learning experience in its own right and is concerned with the provision of developmental feedback to the learners such that students can gain from the feedback provided and adjust their learning style as appropriate (Howarth 2010). Summative assessment is usually undertaken at the end of a period of learning in order to generate a grade that reflects the student's performance.

According to (Howarth 2010), e-Assessment has many advantages over traditional paper-based assessment including: lower long-term costs, instant feedback to students, greater flexibility with respect to location and timing, improved reliability (machine marking is much more reliable than human marking), and enhanced question styles which incorporate interactivity and multimedia. Public and private sector experts have stated that computers, telecommunications, audio or video based media are critical enablers of learning, hence there is a need for assessment tools that measure those essential skills that cannot be captured by traditional tests (Salpeter 2003). Fogel (2010) argues that e-Assessments provide the essential feedback for true 21st century education transformation in which student outcomes can be correlated to a cause-and-effect and in which there is continuous improvement of the e-Learning environment. The public-private coalition known as the 'Partnership for 21st Century Skills' gives a vision of how students should be prepared to face the challenges of the 21st century and underlines the benefits of using technology to give immediate and accurate feedback on student learning (Salpeter 2003).

There are also disadvantages. E-assessment systems are expensive to establish and not suitable for every type of assessment (such as extended response questions). Educators need specific skills to create e-assessment resources, and producing e-assessment tools is a time-consuming process. Electronic testing has also been accused of bringing non-technology students to a disadvantage as students are required to use a computer to enter their answers (Bugbee et al. 1990) (Fairtest 2007).

Recently, several researchers have focused on development and evaluation of e-assessment tools for college-level learning. Doukas et al. (2007) have presented a computer-aided summative assessment system (e-Xaminer) to produce and deliver tests to the Hellenic Air Force Academy students and assess their performance. E-Xaminer uses meta-language concepts to generate tests based on parametrically designed questions. Examinations are delivered via a web-based interface and the system grades the answers submitted by each student. E-Xaminer also allows for implementation of question parameterization and counter cheating measures. The researchers conducted a pilot study that compared paper-and-pencil exams versus the electronic exams in digital electronics, computer science, microprocessors and computer network courses. Results showed that the deviation between the manually graded tests and the electronically graded ones was less than 1% and over 90% of the students thought that the electronic test was equally difficult and preferable to the traditional one. In addition, students expected their automatically assigned marks to better reflect their performance.

Perry et al. (2007) report a project whose goal was to introduce and evaluate a hybrid formative/summative e-assessment tool in an introductory course in Chemical Engineering. The e -assessment tool was created using Respondus (2009) and the e-tests were delivered by WebCT4. Answers from a questionnaire completed by tutors and students showed that over 80% of the students found the feedback provided by the e-assessment tool to be very useful and helpful in determining the areas of learning that needed improvement. Tutors noted that the e-test saved about a day's work and had the main advantage of allowing students to take the test from home.

Andreatos et al. (2008) describe a Matlab-based e-assessment application for an introductory course in analog electronic design. The application included a student interface and an instructor interface. Students designed a transistor amplifier and provided their answers through their interface, and the instructor could automatically evaluate the student answers qualitatively and quantitatively.

Moscinski (2008) reports examples of using Moodle-based tools for summative e-assessment. The e-assessment tools were tested in both theoretically oriented courses on control systems, as well as software and technology oriented courses on computer networks and internet technologies. The questionnaire-based analysis demonstrated the popularity and efficiency of the e-assessment tools and methods both among students and teachers.

## 3 The Surveying E-Assessment Tool

To date, we have developed a prototype e-assessment tool that includes one educational module. The application was developed using Microsoft XNA framework as the base platform and the graphic assets were created in Adobe Illustrator (Adobe 2010). The e-tool runs on standard personal computers and can be interacted with using conventional input devices such as mouse and keyboard. The application consists of 2 components: (1) a Virtual Learning Environment (VLE) that is used by the students to review concepts and procedures and perform surveying exercises; and (2) an evaluation engine that tracks the student's interactions with the program and outputs performance reports.

(1) The educational content of the student VLE focuses on chaining. The goal of this first educational module is to help students visualize and apply the concepts of chaining in the following scenarios: horizontal plane; steep slope; rough terrain; error of standardization of steel tape; error due to temperature; error due to both temperature and standardization. The VLE includes reference documentation on surveying methods and the students learn and practice how to measure the horizontal distance between two points using the proper techniques and instruments. Students are required to use one or several of the following instruments: steel tape to measure the distance between the two points of interests; plumb bobs to set the tape at the points of interests; hand levels to make sure the steel tape is leveled (i.e. the students are measuring the horizontal distance not the slope); tension meter to make sure that the tape is at the correct tension; pins, to mark the points on the ground, so that the measurements can be repeated multiple times. Students are expected to measure the horizontal distance precisely and accurately. Measurement is classified as precise, when students are able to repeat the same measurement multiple times and get the same value or a value with a small acceptable variation (this variation is due to the limitation of the instruments). Accuracy is achieved when the same value is obtained multiple times and that value is the true value, or a value within an acceptable variation.

The VLE has been programmed to allow for 1/16th of an inch variation, i.e. if the student sets up perfectly at the point of interest 2 times in a row, the plumb bob is within 1/16th of an inch from the previous location (this replicates real life settings where the plumb bob will be swinging and will always be at a very small distance from the point). If all the criteria are followed correctly, two consecutive measurements will vary within a 1/8th of an inch. Hence, in the VLE, precision is reached if the same measurement or measurements within 1/8th of an inch or 1/100th of a foot are achieved multiple times. Accuracy is achieved by repeating multiple measurements and therefore compensating for the random 1/8th of inch variation created by the software. Screenshots of the student VLE are shown in figure 1; a video demonstration of the program can be viewed at: http://www2.tech.purdue.edu/cgt/i3/VELS/ . A detailed description of the VLE can be found in (Dib et al. 2010).

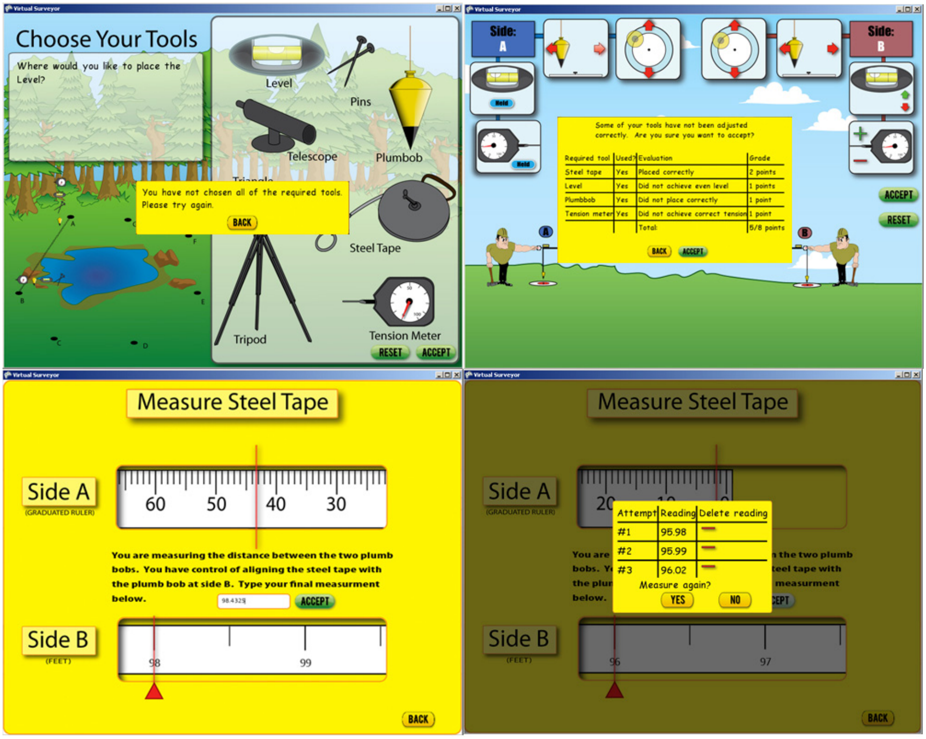


**Fig. 1.** Screenshots of the student's VLE. Clockwise from top left: tool selection screen with feedback to student; tool adjustments with feedback to the students (case of failure to achieve proper adjustments two consecutive times); recording of the tape measurement; option to review multiple measurements and delete outlier or erroneous ones.

(2) The evaluation engine tracks the student's interactions such as (a) the student ability to select the correct tools; (b) the student ability to set up at the correct point of interest; (c) the student ability to hold the tape horizontally, therefore the level has to be perfectly plumb; (d) the student ability to exert the correct amount of tension on the tape, so that the tape can read the horizontal distance; (e) the reading on the tape as a record of the students measurements; (f) the student decision to delete or retain a specific reading (this is used to evaluate the student interpretation of the results); (g) the time spent on each task; (h) the number of correct and incorrect answers. The evaluation engine outputs two types of reports: a summary report that provides formative feedback to the student (figure 2) and a detailed performance report for the instructor in the form of an excel spreadsheet. The instructor uses this report to generate the final grade.

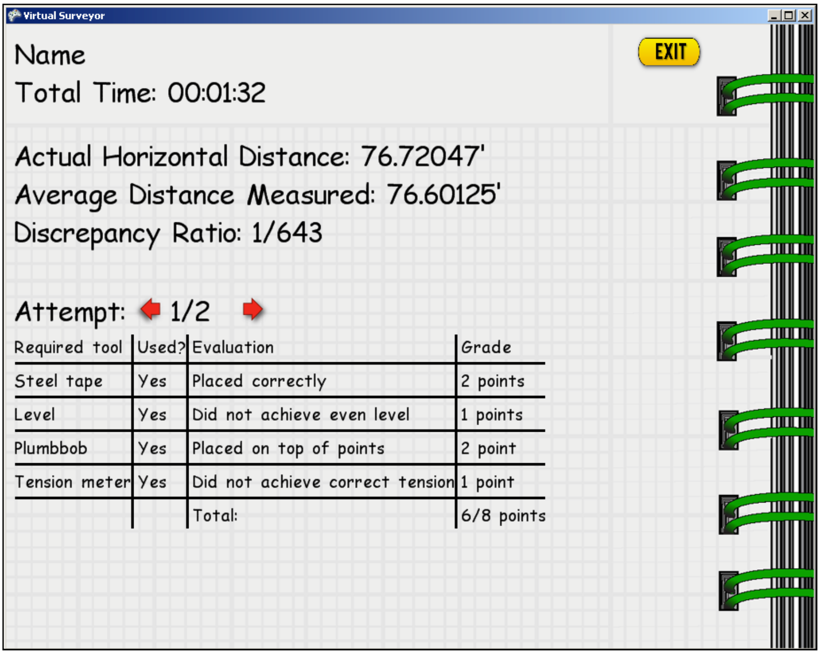


**Fig. 2.** Example of summary report provided to the student at the end of the chaining exercise

## 4 Pilot Study

The objectives of the study were: (1) to determine whether there is a significant deviation between the grades obtained by manually grading the chaining field exercise and the grades generated by the e-assessment tool; (2) to collect feedback from the students on the usefulness and usability of the tool; and (3) to collect feedback from the surveying instructors on the perceived effectiveness and accuracy of the tool at assessing the students' level of competency in chaining.

### 4.1 Subjects

The pool of subjects included 31 male undergraduate students and two faculty with experience in surveying education. The students were enrolled in a Construction Surveying Fundamentals course in the College of Technology at Purdue University. The course is designed to develop the surveying skills necessary to measure horizontal and vertical distances, differences in elevations, horizontal and vertical angles, and to compute tape corrections, traverses, and layout data. Emphasis is placed on accuracy of measurements, precise operation of instruments, completeness in performing laboratory exercises, and keeping accurate field notes. The subjects who volunteered to use the e-assessment tool were students who needed additional credits to improve their grades in the class.

### 4.2 Procedure

The goal of the exercise presented to the students was to measure the horizontal distance between 2 points with the required precision and accuracy. The subjects performed the chaining exercise in two settings: (1) in the field and (2) in the surveying lab using the e-assessment tool. The instructors graded the exercise in both settings.

Setting (1). The students measured the horizontal distance between two points marked on the ground with the help of a colleague. Students used a steel tape, plumb bobs, tension meter, hand levels, and hand clamps and had to ensure that the tape was held horizontally at the two points and the correct amount of tension was exerted in order for the tape to be correctly stretched between the two points. The students recorded their measurements, adjusted for temperature and tape standard error and reported the measurements in a log book. The ability of the instructor to observe in great details the individual students methods and procedures is not feasible due to the settings of the exercise, where at least two students are involved in every individual experiment. In order to limit the time spent performing the testing, and due to the number of the students enrolled in the class, the students would be working simultaneously in groups performing the field test. The instructors timed the exercises and compared the recorded values to the correct values. The students were graded based on how close their measurement was to the true value.

Setting (2). The students were first given guidelines on how to use the program; they were then provided with a set of directions and assumptions for the chaining exercise. The goal of the exercise was to measure the horizontal distance between points A and B with precision and accuracy- the tool presents 6 possible points. The following assumptions were to be considered: the terrain is a rough terrain, the temperature is 86 deg Fahrenheit, and the error in the tape is 1/100th % short, i.e. when the tape measures 100 feet it is in reality 99.99 feet. The students were instructed to use e-assessment tool to measure the average distance between A and B. Once the average value was determined, the students had to adjust for the tape error and the temperature error using the correction formulas. Each individual student used the e-assessment tool, completed the chaining exercise, and received formative feedback from the program under the supervision of the experimenter. The instructors generated the students' grades based on the report (i.e. excel spreadsheet) output by the evaluation engine.

### 4.3 Analysis of Results

Figure 4 shows that the student average e-grade (i.e. the grade obtained with the e-assessment tool) was 65%, whereas the student average m-grade (i.e. the manually generated grade resulting from the field exercise) was 75%. Figure 3 compares the frequency of the grades by letter grade. The same number of students who achieved an "A" in the field test, earned the same grade using the e-assessment tool. 1 out of 4 students was able to earn a "B" in the field exercise and achieved the same grade using the e-assessment tool. None of the students earned an "F" as m-grade while 9 students earned an "F" as e-grade.

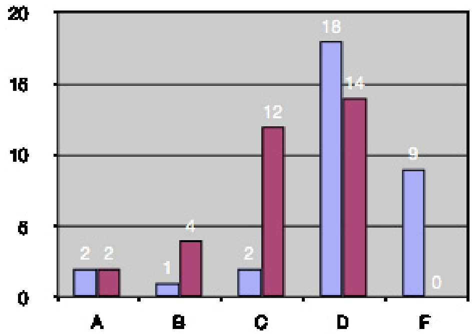


**Fig. 3.** Bar graph showing e-grades (blue) and m-grades (red)

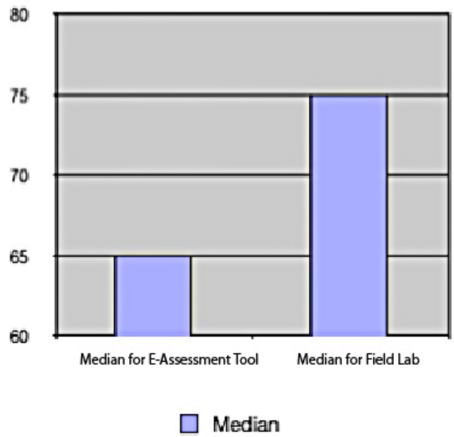


**Fig. 4.** Comparison of e-tool and field test median grades

A weighted kappa measure of agreement, a paired t-test and a sign test were performed in order to determine any correlation between the students' grades obtained by manually grading the chaining field exercise and the grades generated by the e-assessment tool. All three tests show that there is weak agreement between the two sets of grades.

*Weighted kappa measure of agreement*

Table1 shows the strength of agreement between the e-grades (i.e. the grades obtained with the e-assessment tool) and m-grades (i.e. the manually calculated grades earned in the field exercise).

**Table 1.** Agreement table between e- assessment tool and traditional grading

| The FREQ Procedure<br>Table of e-grades by m-grades | | | | | |
|---|---|---|---|---|---|
| e-grades \ m-grades | A | B | C | D | Total |
| A | 2 | 0 | 0 | 0 | 2 |
| | 6.25 | 0.00 | 0.00 | 0.00 | 6.25 |
| | 100.00 | 0.00 | 0.00 | 0.00 | |
| | 100.00 | 0.00 | 0.00 | 0.00 | |
| B | 0 | 0 | 0 | 4 | 4 |
| | 0.00 | 0.00 | 0.00 | 12.50 | 12.50 |
| | 0.00 | 0.00 | 0.00 | 100.00 | |
| | 0.00 | 0.00 | 0.00 | 14.81 | |
| C | 0 | 1 | 1 | 10 | 12 |
| | 0.00 | 3.13 | 3.13 | 31.25 | 37.50 |
| | 0.00 | 8.33 | 8.33 | 83.33 | |
| | 0.00 | 100.00 | 50.00 | 37.04 | |
| D | 0 | 0 | 0 | 13 | 14 |
| | 0.00 | 0.00 | 0.00 | 40.63 | 43.75 |
| | 0.00 | 0.00 | 0.00 | 92.86 | |
| | 0.00 | 0.00 | 0.00 | 48.15 | |
| Total | 2 | 1 | 2 | 27 | 32 |
| | 6.25 | 3.13 | 6.25 | 84.38 | 100.00 |

Table 2 shows the weighted Kappa for measuring agreement between the two tests. When "Kappa = 0", the degree of agreement that the data exhibit is no better than the one expected by chance. "One-sided Pr>= K", or so called "p-value", is a probability that observes data that show a non-independent pattern (i.e. larger kappa value) than the current data under the hypothesis "Kappa = 0". In general, if the p-value is small (<0.05 or <0.01), we reject the hypothesis "Kappa = 0" because if the p-value is that small, the current data is very unlikely to happen under "Kappa = 0". Hence, we conclude that Kappa is not actually 0 but other value. "Exact Test" is used when the sample size is not large and therefore asymptotic assumptions are not met. The p-value of "Exact test" is calculated by enumerating all possible tables with the same fixed marginal frequencies as the current table (tables that have the same row frequency and column frequency as the current table), and accumulating the probabilities for all tables that produce a kappa index that is greater than or equal to the current kappa value. Since the p-value is very small, it is difficult to say that Kappa = 0. In fact, it rarely happens that the degree of agreement is no better than the one expected by chance. Hence, rather than conducting testing, it is recommended to use kappa as index or descriptive statistic measuring the strength of agreement.

Based on the weighted kappa value, we can say the agreement between m-grades and e-grades is weak.

**Table 2.** The Weighted Kappa measure of agreement

| Weighted Kappa Coefficient | |
|---|---|
| Weighted Kappa (K) | 0.3103 |
| Test of HO: Weighted Kappa = 0 | |
| Exact Test | |
| One-Sided Pr >= K | 0.0070 |

Although the larger the Kappa, the stronger the agreement, non-zero kappa and small p-value do not necessarily mean that agreement "exists". For example, table 3 is a contingency table showing responses (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree) to e-assessment tool and field test from a matched data. The weighted kappa of this data is 0.0157 (p-value=0.0001). The data show very weak agreement (otherwise there would be larger values on diagonals).

**Table 3.** Contingency table representing agreement between field test and e-assessment tool

| Frequency | | | | | |
|---|---|---|---|---|---|
| A \ B | 1 | 2 | 3 | 4 | Total |
| 1 | 144 | 2 | 0 | 0 | 146 |
| 2 | 33 | 4 | 2 | 0 | 39 |
| 3 | 84 | 14 | 6 | 1 | 105 |
| 4 | 126 | 29 | 25 | 1 | 181 |
| Total | 387 | 49 | 33 | 2 | 471 |

Table 4 shows the results of the Paired t-test and the Sign test. The "Paired t-test" was used to test whether the difference between the e-grades and the m-grades within each student was zero or not. We computed the differences between the e-grades and m-grades of each student and if a standardized mean of differences was too large (or too small), then we could conclude that e-grades and m-grades are different. In this test, since the p-value (Pr > |t|) is very small, we concluded that e-grades and m-grades are different.

**Table 4.** Paired t-test and Sign test

| Scale: A->95, B->85, C->75, D->45<br>Tests for Location:Mu0=0 | | | | |
|---|---|---|---|---|
| Test | Statistic | | P Value | |
| Student's t | t | 3.961786 | Pr > \| t \| | 0.0004 |
| Sign | M | 6 | Pr >= \|M\| | 0.0042 |

One drawback of the t-test method is that it requires normality of data; in our case this assumption is not met. Therefore we used a Sign test, which is a non-parametric method that does not require such normality of data. The Sign test counts the number of cases where the m-grades are higher than the e-grades and the number of cases where e-grades are higher than m-grades. If there is no difference between e-grades and m-grades, the two numbers would be very similar; and if some difference exists, then either one of two numbers is larger than the other.

In this test, the p-value (Pr >=|M|) was also very small, so we could conclude that e-grades and m-grades are different and specifically, m-grades tend to have greater value than e-grades.

### 4.4 Students' Observations

The students were asked to provide feedback on the usability and usefulness of the e-assessment tool. Table 5 summarizes the students' comments. 76% of the students thought that the e-assessment tool was a good learning tool, as it helped them visualize fundamental steps and procedures. 76% of the students thought it was very helpful in terms of capturing the essence of the chaining exercise and 40% felt that it replicated the field exercise with accuracy. However 60% of the students commented that the e-tool cannot replace the actual field experience. 60% thought it was a good practice tool and some of them recommended that it should be used in the classroom for review and practice. 28% thought it was easy to use, while 8% felt it was difficult at first. 8% of the students observed that the e-assessment tool allowed them to think ahead about every step they needed to make.

**Table 5.** Summary of the students' comments

| | Good Learning tool | Very helpful | Replicate field activity | Good Practice | Allowed to think ahead | Tool easy to use | Tool hard to use at first | Lacks precision | Recommend future use in Class |
|---|---|---|---|---|---|---|---|---|---|
| E-Assessment tool | 76% | 76% | 40% | 60% | 8% | 28% | 8% | 12% | 28% |

### 4.5 Instructors' Observations

The instructors commented that with the e-tool they were able to calculate the individual student grades based on a very thorough report of their performance. Students were assessed based on their ability to select the correct tools the first time, ability to select correct procedures the first time, making more than two readings in order to eliminate the random error generated by the instruments errors, and making the correct judgment by deleting the erroneous and outlier measurements if the deviation was larger than the allowable instrument errors. In the field exercise it was not possible to track all these factors. For instance, students selected the required tools and performed the measuring procedures with a colleague, hence it was not possible to analyze the individual student performance.

## 5 Conclusion and Future Work

The disagreement between the m-grades and e-grades and the observation that the m-grades are generally higher than the e-grades suggest that this difference is due to the ability of the e-assessment tool to track the individual student's performance with higher level of accuracy. Table 6 shows the student interactions that are tracked by the e-tool versus the ones that are recorded by the instructor during the field exercise.

The results of the pilot study are promising. Students found the e-assessment program a useful tool for learning and for providing formative feedback on their level of understanding of chaining concepts and procedures. Instructors commented that it is a very effective summative assessment tool that allows educators to calculate a grade that truly reflects the individual student's performance. Future work will involve extending the content of the application to include 4 additional teaching modules and evaluating the e-tool with a larger sample size.

**Table 6.** Comparison of assessments between e-tool and field test

| | First Time Correct Tools Selection | With Excess tools | Retried Tools Selection | First Time Correct Procedure | Retried procedures | With more than 2 readings | With Deleted Readings |
|---|---|---|---|---|---|---|---|
| E-Assessment tool | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Field Lab | ☐ | ☐ | ☐ | ☐ | ☐ | ✓ | ✓ |

| | Student individual effort | Plumb X axis correct | Plumb Z axis correct | Level correct | Tension correct |
|---|---|---|---|---|---|
| E-Assessment tool | ✓ | ✓ | ✓ | ✓ | ✓ |
| Field Lab | ☐ | ☐ | ☐ | ☐ | ☐ |

| | Time to completion | Average Measurement | Number of repetitions | Number of deleted measurements | True Measurement | Adjustment for Error |
|---|---|---|---|---|---|---|
| E-Assessment tool | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Field Lab | ✓ | ✓ | ✓ | ✓ | ☐ | ✓ |

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