Development of a situated spectrum analyzer learning platform for enhancing student technical skills

Chien-Pen Chuang, Min Jou, Yen-Ting Lin & Cheng-Tien Lu

Department of Industrial Education, National Taiwan Normal University, 162, Section 1, He-Ping East Road, Taipei, 10610, Taiwan

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Electronic engineering industries require technical specialists to operate precision electronic instruments. However, limitations in course designs and equipment availability mean that only a few students are able to use the equipment in practical lessons within a limited timeframe. Also, instruction of techniques and skills are still mostly carried out in traditional lecture formats. Student–instructor and student–student interactions are clearly insufficient. When students encounter difficulties in their lesson, they are unable to obtain immediate assistance, resulting in gaps in their understanding. To address this issue, this study aims to create a situated spectrum analyzer learning platform based on situated learning theory. An interactive educational environment is created to instruct on how to operate a spectrum analyzer. A situated-based learning approach was used so that students would not be limited to memorizing concepts. Instead, they would be allowed to integrate and coordinate what they know to strengthen individual concepts and gain better problem solving skills. Additionally, in order to investigate the effect of the approach proposed, an experiment was conducted to evaluate any differences in learning performance, satisfaction, understanding and technical expertise.

Keywords: situated learning; spectrum analyzer; prior knowledge; interactive learning

Research motives and objectives

Technological developments in electronic engineering industries led to great demands for technical specialists and operators of precision electronic instruments. However, few colleges and universities in Taiwan have such courses. Additionally, due to limits on the specifications, sizes and prices of these precision electronic instruments, only a few are available, giving only a handful of students the opportunity to operate these instruments within the limited timeframe of practical lessons. Additionally, technical instruction is still currently being implemented in traditional lecture format, with distinct inadequacies for student–instructor and student–student interactions. Students are unable to obtain timely assistance when they are uncertain or when they encounter difficult units, leading to knowledge gaps in their learning (Jara et al., 2009). This phenomenon is the reason why college students are commonly unskilled in applying theoretical knowledge when solving practical problems.

Relevant research pointed out that when learners encounter situated course material, they do not end up just memorizing isolated concepts. Instead, situated learning allows...
learners to integrate, coordinate and organize relevant knowledge into a more robust concept structure that helps to foster problem solving skills (Brown, Halabi, MacDonald, Campbell, & Guenette, 2011; Markman, 2005). On the other hand, when facing information or knowledge with little attachment to actual situations, learners’ understanding will be limited to the context of information. Data may be internalized as long-term memory, and links with other relevant knowledge can only be made in the future.

Hence, this study proposes a situated spectrum analyzer learning platform based on the principles of situated learning. An interactive situated-based learning environment is developed to help students learn how to operate and apply a spectrum analyzer. The infrastructure available for web-based learning also helps to solve the issue of insufficient equipment and limited timeframe of practical lessons. The highly interactive learning approach, based on the principles of situated learning, can help improve problem solving skills of the learners. In order to evaluate the proposed approach, an experiment was conducted to evaluate the students’ learning performance and satisfaction. This study also evaluated learners with varying levels of prior knowledge and if there were any differences in their learning achievement, understanding and technical expertise after using the situated spectrum analyzer learning platform proposed by this system.

**Literature review**

**Situated learning**

Situated learning has always been the most popular method in the field of education. Traditional methods that emphasize knowledge without actual application would not be very beneficial. Learners have to be engaged in practical situations in order to obtain corresponding skills. On the other hand, knowledge acquired through situated learning, which emphasizes the importance of actual activities, is more practical and may be further applied or practiced in different scenarios (Anderson, Reder, & Simon, 1996).

Improvements in technology and utilization of computers and multimedia allow situated learning to present teaching materials in a more enriching and flexible manner. Numerous previous researches were carried out on developing learning environments based on the principles of situated learning to maximize learning performance for both students and instructors. One of the most successful methods was anchored instruction (Shyu, 2000). The aim of anchored instruction is to design a learning scenario that is shown using an interactive video platform. Learning contents were presented along with the scenario. Required information and data would be provided as learners explore the plot and solve particular problems. Learners can develop confidence as well as practical and problem solving skills through the learning process, and become independent thinkers and learners (Cognition and Technology Group at Vanderbilt, 1990). Hence, anchored instruction, based on the basic principles of situated learning and cognition, is designed to stimulate learning motivation and to assist learners in thinking and solving complicated problems (Brown, Collins, & Duguid, 1989). This method is also designed to overcome the issue of tacit knowledge. It is believed that learning-by-doing and authentic learning can assist learners in transforming tacit knowledge into explicit knowledge. Knowledge can be flexibly used when relevant knowledge was anchored to specific learning activities, thereby solving the shortcomings of traditional lecture-based lessons.

**Virtual lab**

Practical experience is an important part of education. However, time and expenses required to plan and establish a lab usually exceed the expected budget available to
many teaching institutions. Based on this predicament, educational and engineering professionals proposed virtual labs as a solution. A virtual lab is a type of virtual learning environment (VLE), where students could use virtual equipment and instruments on computers to conduct interactive experiments. Students would be engaged in a situated learning context through a virtual lab environment, and their traditional role of passive learners will be transformed to that of an active participant (Gómez & Rodríguez-Marciel, 2012). Moreover, they would gain the experience akin to conducting an experiment by themselves (Buschiazzo, Leoncini, Zunino, & Scapolla, 2010; Dormido, Esquembre, Farias, & Sánchez, 2005; Hamilton et al., 2012; Jou, Chuang, & Wu, 2010; Jou & Liu, 2012; Jou & Wang, 2013; Jou & Wu, 2012; Ko et al., 2001). Students using computer simulated experiments could also collect experimental data and perform result analysis, hence solving the issue of insufficient lab resources (Guimaraes et al., 2003). Additionally, developments in web-based technologies allow virtual labs to be operated online by users connected remotely. Users could also communicate and exchange experiences with each other (Kapadia, Lundstrom, Fortes, & Roy, 1997). Hence, virtual labs have become a welcoming alternative to the traditional lab, and offers better management, safety, flexibility, as well as an economic and non-polluting means of conducting experiments (Triona & Klahr, 2003; Zacharia & Constantinou, 2008).

In order to improve the effectiveness of lab lessons for both students and instructors, a great deal of research was carried out to develop virtual labs. Butz, Duarte, and Miller (2006) designed an interactive multimedia intelligent tutoring system as a computer simulation and educational software for college-level students learning electronic circuitry for the first time. The students take on the role of a newly employed engineer of the IMIS Company attempting to solve some actual circuitry problems. The students must use theoretical knowledge learned during class to answer these questions. In addition, Record (2005) developed a VLE to improve students’ abilities in troubleshooting circuitry problems. The approach includes a series of web pages, an online quiz with an automated scoring mechanism and a simulator that could be used in a local area network. Hacker and Sitte (2004) designed an educational computer simulation program that incorporated Boolean operations, combinational logic and sequential circuitry. The program also provided logical design procedures to guide student learning.

An introduction on spectrum analyzers

The Fourier Transform is an extremely important and widely used analysis of digital signals in various industries. Fourier Transform converts time amplitude signals from measuring instruments into frequency amplitude, which can then be used to analyze characteristics of the signal’s frequency.

Spectrum analyzers are mainly utilized to show characteristics of the frequency signal. Frequency spectrum of sine waves, square waves and triangle waves are show in Figure 1 (Burk, Polansky, Repetto, Roberts, & Rockmore, 2011; Malvino, 1979; Stanley & Jeffords, 2006). Thus, spectrum analyzers allow users to observe wave frequency changes of the input signal. Spectrum analyzers are extremely important in electronics since it also allow the following analyses: assessing harmonic effects, communication monitoring and frequency testing, phase noise, signal shift, channel efficiency and electromagnetic interference (EMI). This research therefore focused on developing a virtual lab to conduct relevant technical education of using spectrum analyzers.
Situated spectrum analyzer learning platform

To develop the situated spectrum analyzer learning platform for this study, a Client–Server framework was used. In the framework we developed, learners can use web-browsers to login to the platform and access learning resources on the educational server via the Internet. There are four main categories of functions provided by this learning platform, namely, basic learning guidance function, technical operation learning function, knowledge application learning function and operation application learning function, respectively. The following lists the detailed descriptions of these function categories:

- Basic learning guidance function: A basic introduction of the spectrum analyzer was provided to learners, which included a Flash presentation showing the basic operation interface of a spectrum analyzer (Table 1). An assessment was conducted after learning as shown in Figure 2.
- Technical operation learning function: Wizard mode and Flash scripts were developed to provide teaching functions that guide students in learning technical

![Figure 1. Frequency transformation of sine waves, square waves and triangle waves.](image)

<table>
<thead>
<tr>
<th>Topic: basic introduction to the spectrum analyzer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
</tr>
<tr>
<td>------</td>
</tr>
</tbody>
</table>
| Introduction to the spectrum analyzer | (1) Recognizing signals  
(2) Types of spectrum analyzers  
(3) Working principles of the spectrum analyzer |
| Buttons and major components of the spectrum analyzer | (1) Introducing the button functions  
(2) Settings of major variables of the spectrum analyzer  
(3) Major components of the spectrum analyzer |
operations of the spectrum analyzer. Teaching materials provided in this function are described in Table 2. In addition, Figure 3 shows how students can learn technical operations by using this function.

- Knowledge application learning function: This function, different from the two described above, focused on teaching students on how to apply the spectrum analyzer to solve actual problems as described in Table 3. To achieve this aim, Flash animations were utilized to illustrate learning situations as shown in Figure 4.
- Operation application learning function: Wizard mode and Flash scripts were used to help students understand various functions and uses of the spectrum analyzer as listed in Table 4. Students can practice using functions of the spectrum analyzer with the virtual version provided on the computer. During the learning process, scenes will constantly change to provide corresponding textual and audio explanations as the students perform various operational procedures. This design would allow students to understand the reason behind every step and view the subsequent results as shown in Figure 5.

**Experiment**

In order to evaluate student learning effectiveness when using the proposed approach, the experiment adopted a one-group pretest–posttest design for evaluating this pilot study based on the school curriculum (Campbell & Stanley, 1963). Experimental subjects were 31 university sophomore students using the proposed approach for two months.

<table>
<thead>
<tr>
<th>Table 2. Teaching materials on the technical operations learning function.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic: technical operations of the spectrum analyzer</td>
</tr>
<tr>
<td>Unit</td>
</tr>
<tr>
<td>(1) Checking instrument functions</td>
</tr>
<tr>
<td>(2) Frequency settings</td>
</tr>
<tr>
<td>(3) Span settings</td>
</tr>
<tr>
<td>(4) Amplitude settings</td>
</tr>
<tr>
<td>(5) Resolution bandwidth</td>
</tr>
<tr>
<td>(6) Marker settings</td>
</tr>
<tr>
<td>(7) Peak search settings</td>
</tr>
<tr>
<td>(8) Trace settings</td>
</tr>
</tbody>
</table>
The experiment conducted a pretest for assessing students’ prior knowledge on spectrum analyzers and a posttest for evaluating learning achievements after going through the situated learning process. A further evaluation was conducted to investigate differences in the effectiveness of web-based learning for learners with different degrees of prior knowledge. A learning satisfaction questionnaire was also used to measure students’ learning satisfaction on the situated spectrum analyzer learning platform. Figure 6 displays the experimental procedure.

Three research methods, as described above, were utilized in this experiment to evaluate the effectiveness of the proposed approach. This included a pretest for prior knowledge on spectrum analyzers, a posttest for learning achievement on spectrum analyzers and a learning satisfaction questionnaire on the situated spectrum analyzer learning platform. The question
banks were pretested, and exhibited good reliability and validity scores of above 0.7. This showed that the items had internal consistency, good reliability and effectiveness.

**Experimental results**

**Learning achievement analysis**

Table 5 shows the learning achievement of 31 sophomores from the department of electronic engineering before and after two months of learning with the situated spectrum analyzer learning platform.

Table 5 shows that the mean and standard deviation of the posttest (81.06 and 8.53) were better than those of the pretest (51.77 and 10.61). Further analysis included a t-test to determine whether the knowledge level of spectrum analyzers before and after undergoing the situated spectrum analyzer learning platform was the same. Results provided in Table 5 show that significant differences exist between the posttest and pretest ($t(60) = -12.85, p < 0.05$). A paired t-test was then used to analyze the pretest and posttest. Results are shown in Table 6 and revealed that the proposed approach could help students learn about spectrum analyzers ($t(30) = 13.09, p < 0.001$). The results implied that students could benefit from the situated spectrum analyzer learning platform by improving their knowledge acquisition skills.

**Comparisons of learning achievements of students with different prior knowledge after using the situated spectrum analyzer learning platform**

This study applied independent t-test to analyze differences in learning achievement of students with different prior knowledge after using the situated spectrum analyzer learning
platform. Results are shown in Table 7, and those who had low prior knowledge achieved a learning achievement of 76.75, while those who had high prior knowledge exhibited a learning achievement of 83.79. In addition, two paired $t$-tests were further used to analyze the pretest and posttest of low and high prior knowledge groups. Results were shown in Table 8, and indicated that there were significant differences in the two groups with regard to the pretest and posttest results (low prior knowledge group: $t(11) = 15.43$, $p < 0.001$; high prior knowledge group: $t(18) = 7.90$, $p < 0.001$). The above results imply that students with higher prior knowledge had better learning achievement in using the situated spectrum analyzer learning platform than those with lower prior knowledge.

**Figure 6.** Experimental design of the situated spectrum analyzer learning system.

**Table 5.** $t$-test analysis in the pre and posttest on using the spectrum analyzer.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Number</th>
<th>Mean</th>
<th>S.D.</th>
<th>Degrees of freedom</th>
<th>$t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>31</td>
<td>51.77</td>
<td>10.61</td>
<td>60</td>
<td>$-12.85^*$</td>
</tr>
<tr>
<td>Posttest</td>
<td>31</td>
<td>81.06</td>
<td>8.53</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*$p < 0.05$.

**Table 6.** Results of the paired $t$-test for learning improvement between the pretest and the posttest.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Number</th>
<th>Mean</th>
<th>S.D.</th>
<th>Degrees of freedom</th>
<th>$t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posttest–pretest</td>
<td>31</td>
<td>29.29</td>
<td>12.458</td>
<td>30</td>
<td>$13.09^{***}$</td>
</tr>
</tbody>
</table>

$^{***}p < 0.001$. 

platform. Results are shown in Table 7, and those who had low prior knowledge achieved a learning achievement of 76.75, while those who had high prior knowledge exhibited a learning achievement of 83.79. In addition, two paired $t$-tests were further used to analyze the pretest and posttest of low and high prior knowledge groups. Results were shown in Table 8, and indicated that there were significant differences in the two groups with regard to the pretest and posttest results (low prior knowledge group: $t(11) = 15.43$, $p < 0.001$; high prior knowledge group: $t(18) = 7.90$, $p < 0.001$). The above results imply that students with higher prior knowledge had better learning achievement in using the situated spectrum analyzer learning platform than those with lower prior knowledge.
Evaluating spectrum analyzer operation skills of students with different levels of prior knowledge after using the situated spectrum analyzer learning platform

This experiment was conducted to evaluate operating skills with an actual spectrum analyzer. Participating students first learned how to operate the instrument in a virtual and online setting. They were then required to operate an actual instrument in a technical operation assessment to investigate whether skills were correctly transferred.

Table 9 shows technical operation assessment results of students, with different levels of prior knowledge, after using the situated spectrum analyzer learning platform. Students with low prior knowledge scored 88.23 in instrument operations, while those with high prior knowledge scored 87.17. The results imply that prior knowledge and final technical operating skills have little correlation. To further investigate the phenomenon, an interview was conducted to understand the students’ perception of the assessment. Interview results show that students with high prior knowledge tend to be less careful in their technical operation assessments. Difference between the two groups of students was small. Overall, students improved from a mean score of 49.84 points to 87.70 (an improvement of 37.86 points), which was very significant.

Technical operation assessment for spectrum analyzers include ‘searching for broadcasted signals’, ‘testing cell phone signals’, ‘testing wireless network signals’ and ‘EMI testing’, with average scores of each category at 87.42, 89.84, 90.65 and 82.58, respectively, and average completion time of 5 min 20 sec, 7 min 3 sec, 3 min 4 sec and 6 min 28 sec, respectively. This showed that learning effectiveness improved after using the situated spectrum analyzer learning platform.

### Table 7. t-test results for pretest and posttest of the low and high prior knowledge groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Numbers</th>
<th>Mean (pretest)</th>
<th>Mean (posttest)</th>
<th>S.D.</th>
<th>Degrees of freedom</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low prior knowledge</td>
<td>12</td>
<td>41.25</td>
<td>76.75</td>
<td>7.88</td>
<td>29</td>
<td>-2.41*</td>
</tr>
<tr>
<td>High prior knowledge</td>
<td>19</td>
<td>58.42</td>
<td>83.79</td>
<td>7.94</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05.

### Table 8. Paired t-test results of pretest and posttest of low and high prior knowledge groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Numbers</th>
<th>Mean</th>
<th>S.D.</th>
<th>Degrees of freedom</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low prior knowledge Posttest–pretest</td>
<td>12</td>
<td>35.5</td>
<td>8.21</td>
<td>11</td>
<td>15.43***</td>
</tr>
<tr>
<td>High prior knowledge Posttest–pretest</td>
<td>19</td>
<td>25.37</td>
<td>13.45</td>
<td>18</td>
<td>7.90***</td>
</tr>
</tbody>
</table>

***p < 0.001.

### Evaluating spectrum analyzer operation skills of students with different levels of prior knowledge after using the situated spectrum analyzer learning platform

This experiment was conducted to evaluate operating skills with an actual spectrum analyzer. Participating students first learned how to operate the instrument in a virtual and online setting. They were then required to operate an actual instrument in a technical operation assessment to investigate whether skills were correctly transferred.

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### Table 9. Technical operation assessment results of the situated spectrum analyzer learning platform.

<table>
<thead>
<tr>
<th>Group</th>
<th>Numbers</th>
<th>Pretest average</th>
<th>Technical operation score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low prior knowledge</td>
<td>12</td>
<td>41.25</td>
<td>88.23</td>
</tr>
<tr>
<td>High prior knowledge</td>
<td>19</td>
<td>58.42</td>
<td>87.17</td>
</tr>
</tbody>
</table>
Table 10 shows the overall satisfaction feedback results obtained using a learning satisfaction questionnaire. Mean values for each item were between 3.47 and 3.80, with standard deviations between 0.78 and 0.97. Results also showed that significant differences existed for all items. To conclude, overall student rating of the situated spectrum analyzer learning platform proposed by this study was satisfactory.

### Conclusion

This study developed a web-based situated spectrum analyzer learning platform to provide a solution for inadequate equipment and practical lesson time. Principles of situated learning were utilized to develop a highly interactive learning environment to help improve problem solving skills. Experimental results show that students exhibited significant learning effectiveness after using the proposed system. Additionally, students with different levels of prior knowledge achieved significant improvement, showing that the proposed system provided actual assistance to technical training. Finally, students were, on average, satisfied with the learning process as evaluated by a learning satisfaction questionnaire. Hence, the proposed approach was able to provide cognition and technical education results on the complex spectrum analyzer. Additionally, concepts adopted in this research were well received by the industry, which also provided extensive assistance in promoting their use. Thus, practical values of the Situated Spectrum Analyzer Learning Platform developed in this research were well demonstrated. For future development, this study shall continue to improve relevant features of the learning platform in order to provide a more complete set of educational functions. This study utilized a one-group pretest and posttest design. Results were more likely to be confounded by individual skills and external history due to a lack of comparative controls. Hence, this study will attempt to increase sample number and establish a control group in future research in order to obtain a more externalized and comparative result.

### Acknowledgements

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Notes on contributors

Dr. Chien-Pen Chuang is a professor in the Department of Industrial Education at National Taiwan Normal University. His research interests include Technical and Vocational Education, Instructional Strategies and Designs, and Educational Technology.

Dr. Min Jou received his Ph.D. in 1994 from Rensselaer Polytechnic Institute, Troy, New York. He is a professor in the Department of Industrial Education at National Taiwan Normal University. He received the Distinguished Professor award in 2013. His research interests include technological education, application of ICT technology in education, and mechatronics. Dr. Jou is currently an editorial board member of the Creative Education, International Journal of Electronic Democracy, and The Turkish Online Journal of Educational Technology. He is a member of ASEE, SEFI, ASHE, and SEDA.

Dr. Yen-Ting Lin is a postdoctoral researcher in the Department of Industrial Education at National Taiwan Normal University. He received his Ph.D. from the Department of Engineering Science at National Cheng-Kung University in 2010 and his MS degree from the Department of Computer Science and Information Engineering at Southern Taiwan University in 2006. His research interests include ubiquitous/mobile learning, collaborative learning, knowledge management, and artificial intelligence.

Cheng-Tien Lu received his MS degree from the Department of Industrial Education at National Taiwan Normal University. His research interests include electronic engineering.

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