

## **EVALUATION OF THE USABILITY OF DIFFERENT VIRTUAL LAB SOFTWARE USED IN PHYSICS COURSES**

**Özden KARAGÖZ, Nesrin ÖZDENER**

*Marmara University, TURKEY*

---

**Abstract.** In recent years the use of virtual lab software has become ubiquitous in education settings. The purpose of the current study is to develop an Evaluation Scale to allow the easy and fast assessment of virtual lab software. During the development of the Evaluation Scale, theoretical and experimental studies investigating the effects of different software on learning, particularly in terms of usability, were utilized. The Evaluation Scale was created by adding new attributes to pre-existing scales, and comprises three sections – attributes related to the interface of the software; attributes related to its use as a material in education; and attributes related to product and service support – and 79 items. Testing of the Evaluation Scale was carried out using two different virtual lab programmes, with the help of a checklist. The evaluation was carried out by physics teachers and academics that had previously used similar software, and consistency between the results was considered to represent inter-rater reliability. At the end of the study, the usability of the Evaluation Scale was tested, and the instructor evaluations regarding the

usability characteristics considered sufficient and that require improvement in virtual lab software were also investigated.

*Keywords:* virtual labs, usability, evaluation scale, physics education

---

## **Introduction**

The need for technology increases with the development of special teaching methods in education. The variety of materials used in education increases in parallel with the rapid change in technology. This diversity provides teachers with assistance in teaching, while presenting distinctive environments and applications for students relating to their field of study. Recently, virtual labs have become ubiquitous in science and engineering education. Virtual labs enable students to repeatedly carry out experiments in a safe environment during lessons. Jeschke et al. (2001) and Budhu & Coleman (2002) assert that the short-term purpose of virtual lab programmes is to support actual physics laboratories, while their long-term purpose is to replace them. Virtual labs create a convenient learning environment that takes into consideration the individual's characteristics (Guzzi et al., 2005; Noor & Wasfy, 2001). These programmes also provide an affordable, safe, easy and ideal working environment.

In addition to the information regarding in which field and for what purpose the virtual labs will be used, their attributes should also be specialized to their respective field. For example, the virtual lab to be used in physics courses should have different attributes to that one used in biology courses. This situation makes field-specific studies more necessary. Evaluation Scales prepared specifically for different fields would be beneficial for teachers and students alike. In order for virtual labs to make the expected contribution to students' achievement, they should be well-designed and have the required usability characteristics. Such software, which is preferred for individual edu-

cation and used for students' self-study, should be correctly designed and have functional software features. The literature review conducted showed that different perspectives were adopted regarding the usability attributes that a virtual lab programme should have, and that different attributes were used in each study. Some of these studies listed simulation software attributes (Budhu & Coleman, 2002; Nikoukaran et al., 1998; Subramanian & Marsic, 2001), while others investigated the use of simulation software in education (Gabbard, Hix & Swan, 1999; Jensen *et al.*, 2004; Serra et al., 1999; Weissmann & Yahel, 1999).

All these distinctive perspectives create a problem for school administration, teachers and students, who are faced with the following question: Which attributes should be taken into consideration in the selection of virtual lab software? Bringing together and developing the attributes formed from different perspectives would provide benefits to teachers and students using virtual labs. Indeed, many studies indicate that teachers' attitudes towards computers become more positive as their knowledge and experiences regarding computers increase (Galanouli et al., 2004; Levine & Donitsa-Schmidt, 1998; Potosky & Bobko, 2001; Rozell & Gardner, 1999; Williams et al., 2000). Increasing the awareness of teachers regarding the selection and evaluation of software will also have positive impacts upon their attitude towards such software.

The purpose of this study is to develop an Evaluation Scale that can be used to evaluate the usability of the virtual lab software used in physics lessons. Furthermore, the usability of two different virtual lab programmes was evaluated with the help of the Evaluation Scale developed. The test stage of the Evaluation Scale was carried out, then the evaluation results of the teachers were examined.

## Literature

Virtual physics labs are highly interactive software, comprising simulations of real physics labs customized for the needs of researchers and students (Noor & Wasfy, 2001). These software programmes provide students with the opportunity to study under the control and within the knowledge of the teacher, and to learn using trial and error (Guzzi et al., 2005). The most important attribute of virtual physics labs is that they should have a highly interactive user interface. Users are able to perform experiments using the laboratory materials in any order by moving the objects using input devices (Scherp, 2002).

According to Özdener (2004), virtual labs are tools that simulate phenomena that cannot be investigated or observed in natural environments or in cases where the lab facilities are limited. Thanks to these programmes, users have the opportunity to learn by experimenting and testing using different parameters. For example, they provide the opportunity to perform experiments in different environments with different gravitational forces (e.g., on another planet or at the poles), and to investigate the incidents in detail by controlling the time (e.g., slowing down the movements of electrons in a conductor for easy observation). Furthermore, virtual labs also provide the opportunity to conduct investigations and experiments without harming any living creatures. Virtual labs are capable of simplifying experiments based on the user's skill level. For example, they enable users to understand the subject and solve the problem by showing multiple forces affecting an object directionally.

### *Usability and attributes*

Usability is a quality attribute that assesses how user-friendly the user interface is. It is identified by Nielsen<sup>1)</sup> and Gündoğan (2003) as having five important quality components: (1) *Learnability*: how easy it is for users to accomplish basic tasks the first time they encounter the design. Keeping com-

pliance to the standards that the user is accustomed is the functional usage of the program. Amongst such factors influencing the same are included the design of the interface, language used, as well as its similarities in application of certain tasks (like opening-closing of the program) to other programs; (2) *Efficiency*: once users have learned the design, how quickly they can perform tasks. After the users receive usability training with respect to the program, they are capable of reaching the level to meet their requirements and carry out the procedures in very short notice; (3) *Memorability*: when users return to the design after a period of not using it, how easily they can re-establish proficiency. Is the nature of the program being easily remembered by the users, and therefore, the program is required to comply with the standards and have a simple interface; (4) *Errors*: how many errors users make, how severe these errors are, and how easily they can recover from these errors. Is its usability in such nature as avoiding the users making mistakes, in an active manner under accurate directives? It should enable facilities for the user to compensate any errors made; (5) *Satisfaction*: how pleasant it is to use the design. The usage of the program should be easy, with an esthetic, functional interface design, capable of meeting requirements of the users. The users should be able to carry out any applications they so desire, in an active manner without contradicting in their applications.

Another key quality attribute that affects usability is utility. A positive reply to the question “Does it do what users need?” will be an important factor in improving the usability of the programme. Continuous use of the programme, the motivation for learning, being clear, and being beneficial are also important (Ezginci et al., 2006).

According to Malloy & Jensen (2001), the usability attributes of virtual labs should be as follows: (1) *Password Access*: To enable the programme to make individual evaluations, users should be allowed to log-in to the system using an individual password. The performance of each and every

user should be measured and assessed by entering into the system under its own user name as well as password; (2) *Examples*: The programme should provide users with examples in order to improve usability. There should exist in the program sample experiments demonstrating how any experiment structure is created. Such samples should be rather in the form of demonstrations and self-explanatory; (3) *Selecting the Independent Variable*: The programme should provide users with the facility to select any object and to create any experiment mechanism. While creating the experimental structure, the user should be independent. It should be able to create different experimental structures and observe the results of the same in a manner similar to those in real life; (4) *Representing the Experimental Design*: The programme should be capable of reporting the experiments performed by users. Any experimental structures created should include presentations that are both mathematically accurate, and also with the events depicted being similar to those in real life. They should enable the user to report the results pertaining to each and every experimental structure and compare the same under different parameters; (5) *Setting the Dependent Variable*: The programme should contain environments that encourage users to research. It should enable the comparison of the results under different features of the experimental structure so created; (6) *Authoring*: Users should be enabled to find different examples relating to the subject, to create the mechanisms explained, and to see and interpret the results. The user is free to create experimental structures, and it should be able to observe the results of any experiment created in a manner similar to those events in real life; (7) *Data Analysis*: On the basis of their knowledge of the research design they create, users must choose appropriate data analyses. While creating the experimental structure, each and every object selected should be equipped with data (such as upper and lower limit values) in compliance with its features in real life; (8) *Conclusion and Research Report*: Users should be able to see the results of the experiment they created and the

experiment mechanisms they operated. Results of the experiment should possibly be presented graphically as well as in the form of reports, so as to act as exact equivalents of those in real life. At the end of the experiment, the program should be make mathematical calculations in an accurate manner and display a result similar to that in real life.

Virtual labs<sup>2)</sup> should have strong presentation that satisfies users. The content should be plain and clear, and not cause misunderstanding, and the subject should not divert the user from the relevant targets. Students should be able to select the experiment tools by looking at their shapes, placing them in the working environment using the mouse, and changing the links freely (Serra et al., 1999).

According to Sanchez et al. (2004), students should be able to test the modules they create and change the attributes of the experiment tools. Furthermore, the links and experiment tools that have been selected for changing should turn a different color. Before adding a tool to the experiment mechanism, users should be able to test whether they are faulty, and to derive preliminary information about the operating order of the programme (Nikoukaran et al., 1998; Serra et al., 1999). Studies show that virtual lab programmes should be capable of running on a web browser using a form of presentation that tests and interprets the experiment mechanism created by students (Ezginici et al., 2006; Gustavsson, 2002; Keyhani et al., 2002; Lin et al., 2002; Shen, 1999; Yeung & Huang, 2003).

Bateman et al. (1997) and Harrell & Tumay (1995) investigated the human-computer interaction by developing a variety of scales in a number of studies. The attributes prescribed in the scales show that educational software should be easy-to-use, motivating, and support learning in a number of ways.

## **Method**

The research model is both descriptive, aiming to determine the attributes of the virtual lab software developed for use in secondary education physics courses as a result of the literature review, and methodological, aiming to develop an Evaluation Scale. Firstly, some of the virtual laboratories available were examined and an Evaluation Scale comprising 110 items was developed in line with the literature review. Subsequently, the scale items that were difficult to understand, determined to be immeasurable, or that partly match up with each other were identified, and necessary corrections were made as a result of the pilot work carried out. Based on the final arrangements, a dual Likert-type Evaluation Scale comprising 79 items was developed.

### *Methodological study group*

The Evaluation Scale was evaluated by forty nine physics teachers and five academics that had previously used virtual lab programmes.

### *Data collection tools*

At the development stage of the Evaluation Scale, theoretical studies that demonstrate the attributes required for educational software and offer recommendations were reviewed and the usability attributes required for educational software were identified. Furthermore, studies conducted in the field of learning psychology investigating the usability of different software during the process of learning were reviewed; thus, the theoretically identified attributes were supported by the results of empirical research, and new attributes were added.

Companies that develop simulation software and books dealing with human-computer interaction were also examined, with the data obtained forming the scale attributes. It was ensured that these attributes were of a

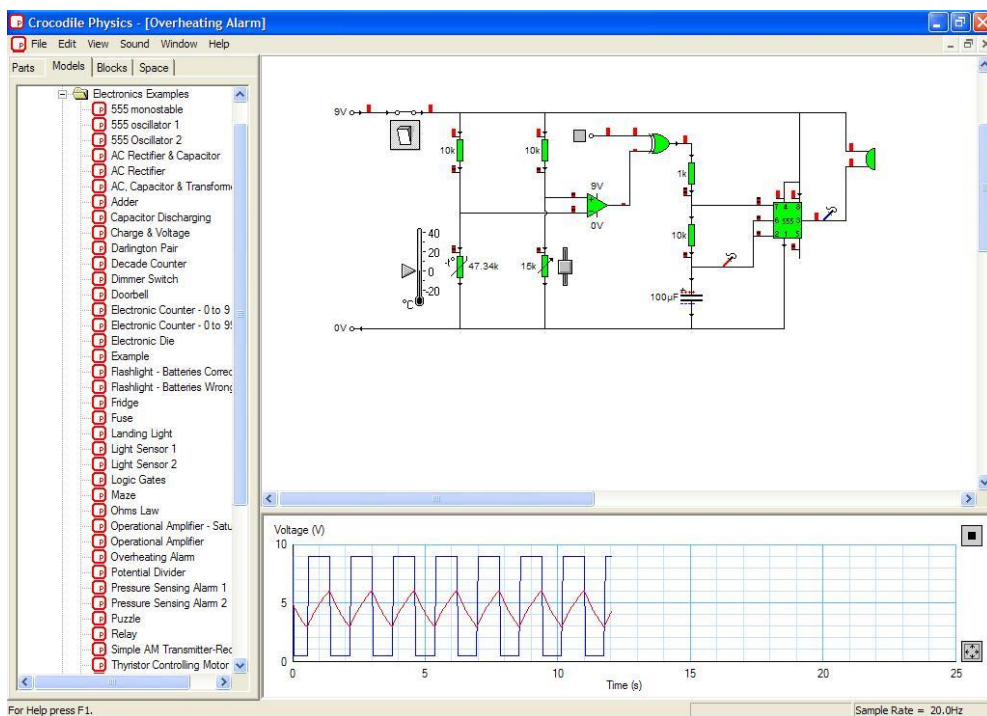


quality that could be easily understood and not open to different interpretations. For example, the Evaluation Scale items were prepared in such a way that the respondent can only choose “Yes” or “No” answers. The respective study groups used two virtual lab programmes, so the symbol “C” indicates Crocodile Physics 401, and the symbol “E” indicates Edison4.

### *The virtual lab programmes used in this study*

The following virtual lab programmes were obtained by contacting the companies that develop them.

*Crocodile Physics 401:* This programme was developed by the Crocodile Company, and provides a laboratory environment for some secondary education physics subjects (dynamics, kinetics, forces, waves, optics, and electricity).



**Fig. 1.** A screen capture of an experiment mechanism created using the Crocodile Physics 401 virtual lab programme

As can be seen from Fig. 1, there is a menu on the left-hand side of the screen providing example models classified according to subjects, learning objects, and the possibility of arranging the experiment environment. There are short-cut buttons at the top of the screen that allow the user to make changes to the experiment mechanism (e.g., copying, deleting, locking graph on/off, print, etc.). The experimental settings in the programme can be used both as symbols and pictures. Furthermore, five different users can simultaneously use the programme on a computer network.

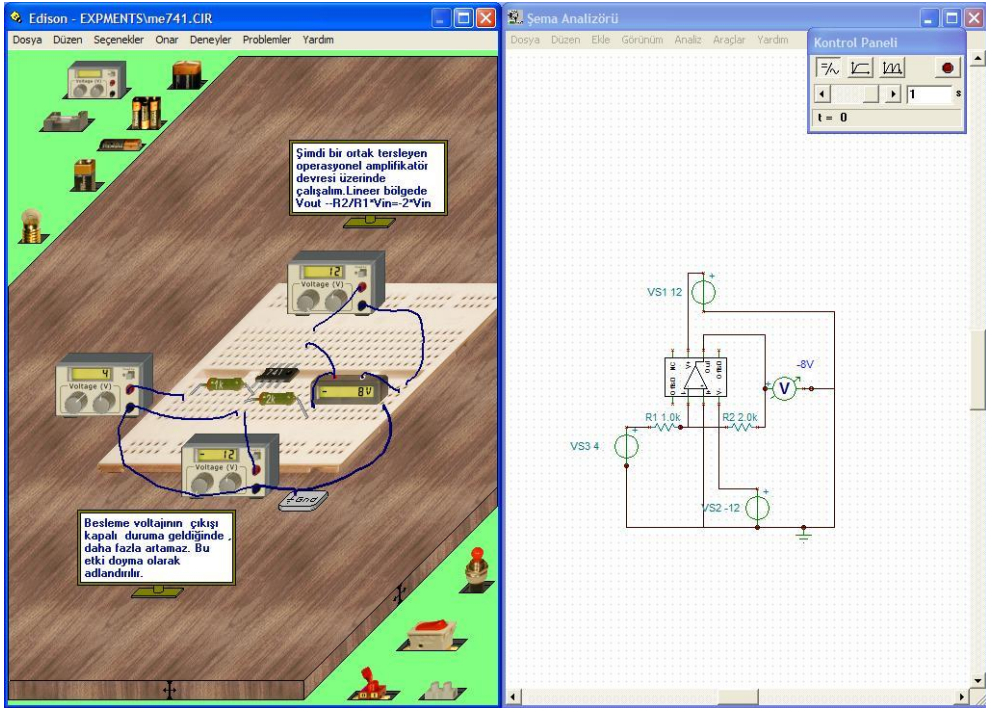
Users are able to select the required object from among the ones provided by the programme, move it into the experiment environment using the mouse, carry out necessary adjustments (rotating, changing values) and combine them. The experiment mechanisms have real-life features (sound, light, etc.) and the programme can create graphs (energy vs. time, speed vs. time, etc.) for the learning object selected. The programme also provides sample models and experiment sets.

*Edison4*: This programme was developed by the Designsoft Company, and provides a laboratory environment for electricity/electronics subjects in secondary and higher education physics curricula.

As can be seen from Fig. 2, the interface screen comprises three separate windows: the Control Panel, for making adjustments relating to the objects being used, such as adjusting the type of current; the Schema Analyser, which symbolically displays the objects selected by the user and provides the work space; and Edison, a 3D view, providing users with a working environment that looks like a real laboratory. The programme allows simultaneous use by multiple users on a computer network.

Users are able to select the required object from among the ones provided by the programme, move it into the experiment environment using the mouse, carry out necessary adjustments (rotating, changing values) and combine them. The experiment mechanisms have real-life features (sound, light,

etc.) and the programme can create graphs (energy vs. time, speed vs. time, etc.) for the learning object selected. The programme also provides animations about how to create the experiments, and allows the use of sample experiment and problem sets.



**Fig. 2.** A screen capture of an experiment mechanism created using the Edison4 virtual lab programme

### *Collection and Analysis of the Data*

As in much qualitative research, the software analysis stage of the current study creates a situation partly based on interpretation. Because this significantly affects the reliability of this study, following the preparation of the analysis form, the thirteen participants forming the study group were requested to fill in the form using the software programmes. The consistency between the results of the inspection was considered to verify the reliability of the inspection (inter-rater reliability).

The scale developed for the purpose of determining the usability attributes of the virtual lab programmes was classified under three main headings, identified based on the literature review: attributes related to the interface of the software; attributes related to its use as a material in education; and attributes related to product and service support (Nikoukaran et al., 1998; Gündoğan, 2003). Two different programmes were used to evaluate the Evaluation Scale, and the attributes specified in Tables 1–3 were sought.

**Table 1.** Attributes of the Evaluation Scale relating to the User Interface

	<b>Attributes</b>
1	Can be used in the native language.
2	Can also be used in different languages.
3	Is compatible with the operating systems (Win XP, Vista, Linux, etc.).
4	Does not raise difficulties during the installation process.
5	Provides secure log-in opportunity for different users.
6	Requires extra hardware to be used (touch screen, microphone, etc.). Required hardware: .....
7	The experiment mechanisms created can be shared over the Internet and the Intranet.
8	Holds to the standards accustomed by users (Menus, symbolic icons, etc.).
9	Users have the latitude to select and use any objects they want.
11	Has an interactive structure.
12	Creates a motivating environment for the user before starting experiments (For example, asks questions about the subject or displays up-to-date experiment mechanisms.)
13	Provides users with the opportunity to run the modules again and again.
14	Provides users with the opportunity to change the values of the experiment tools.
15	Starts with the statue of being not empty. (e.g. “1 kg” for a mass selected by user).
16	Users can adjust the running speed of the experiment setting as they wish.
17	Screen arrangement is printable.
18	Provides users with the opportunity to run multiple experiments simultaneously.
19	Provides the opportunity to change the common attributes (speed, mass, etc.) of multiple experiment settings simultaneously.
20	Provides undo and redo functions.
21	Provides users with the opportunity to cancel while running.
22	Provides the opportunity to resume a previously created experiment.
23	Menus have easy-to-access location on the working environment.
24	Screen image can be copied to another environment.
25	Snap shots of the modules can be taken.

26	Has the multi-tasking feature (i.e. while a model is running, a new model can be designed simultaneously).
27	Provides interface to other software.
28	Provides auxiliary tools (calculator, etc.).
29	Supports paths such as minimum and maximum values for components (i.e. it has the bottom and top limits the objects can get in the real life).
30	Provides video-voice conference opportunity during multiple-user operation.
31	Has timelines showing the real-life duration of applications.
32	Provides the opportunity to correct an error in the experiment setting.
33	When required, inactive or broken down tools can be added to the experiment sets.
34	When broken down tools are provided in the laboratory environment, it provides the opportunity to test them.
35	Provides users with the opportunity to repair any inactive or broken down tools in the program.
36	Provides users with the opportunity to change the working environment.
37	Provides the opportunity to assign a password to an experiment setting created.
38	Some tools of the experiment setting created by users can be classified as required.
39	Has the capability to reject out-of-rule data (giving successive different commands, selecting more than one tool simultaneously, etc.) which could prevent operation of the program.
40	Has a shortcut icon on the desktop.
41	Allows use of shortcut keys (such as Ctrl+C, Ctrl+V) for rapid operation of the program.
42	Allows users to work both over the Internet and from the CD.

Remark: the answers should be 'yes' and 'no'

**Table 2.** Attributes of the Evaluation Scale relating to the use of the virtual lab program as a material in education

	<b>Attributes</b>
1	It is capable of covering the curriculum of the target group.
2	The sample models match with the curriculum of the identified target group.
3	There are difficulty levels for experiments.
4	Makes curriculum recommendations to teachers for effective use.
5	Makes studying program recommendations to students for effective use.
6	Supports different teaching methods (project method, problem solving, etc.).
7	Convenient for use in group works.
8	Users are informed of their level.
9	Users can be evaluated based on their performance.
11	Users are provided immediate feedbacks.
12	Encourages users to do research (asking questions, proposing projects, etc.).
13	Experiment tools and sample experiments match with the learning and teaching attributes.

14	Contains tutorials.
15	Provides examples relating to the subject.
16	The experiment tools show parallelism with the improvements in technology.
17	Examples show parallelism with the improvements in technology.
18	Has a structure that would assist in development of creativity of students by providing the opportunity to perform experiments infinitely.
19	Allows users to manually create the graph relating to the experiment setting created (i.e. user draw the points, curves, etc. manually).
20	Combines all subjects relating to a specific field in a single module.
21	Provides the opportunity to save and load any previously performed works.
22	Has icon library. Icons can be called and run from the library and new icons can be stored in the library.
23	Provides different working environments depending on the level of users (normal, explanatory, instructive, etc.).

Remark: the answers should be 'yes' and 'no'

**Table 3.** Attributes of virtual lab programs as a product and service support

	Attributes
1	Has help menu.
2	Provides information to users about the experiment tools and experiment environments.
3	Provides detailed information about the fields of use.
4	Provides information and evaluations about the user groups (age, school, grade, etc.).
5	Provides user's manual.
6	Users are informed of any changes or improvements to the program.
7	Technical information can be obtained and consultancy services are provided for the program when necessary.
8	Scientific seminars are organized about the program in various places.
9	Users can send their recommendations and complaints by:: e-mail ( )      chat ( )      another method..... to the concerned people.
10	There is a discussion and communication platform on the Internet for the users of the program.
11	A free-of-charge trial version of the program is provided when requested.
12	The trial version can be obtained from, cd ( )      web ( )
13	Information about the program can be obtained in the Internet environment.
14	There is a 7/24 free-of-charge help line for the users of the program.

Remark: the answers should be 'yes' and 'no'

The results of the evaluation performed by academics for the two virtual lab programmes using Table 1 are provided in Table 4. Accordingly, it can be seen that Crocodile Physics 401 has 61% and Edison4 59%, of the attributes listed in Table 1. Even though the reason has the most of attributes that they have for interface usability, it shows that it is needed to be developed. Attributes relating to the use of the virtual lab programmes as a material in education are shown in Table 2. The results of the evaluation performed by academics for the two virtual lab programmes using Table 2 are provided in Table 4. Accordingly, it can be seen that Crocodile Physics 401 has 57% and Edison4 54%, of the attributes listed in Table 2. Even though the programs have many attributes that are stated before, for using effectively in education, they should be developed. The attributes of virtual lab programmes in regard to product and service support are listed in Table 3. The results of the evaluation performed using Table 3 are provided in Table 4. Accordingly, it can be seen that Crocodile Physics 401 has 59% and Edison4 66%, of the attributes listed in Table 3.

**Table 4.** The standard deviation relating to evaluation scores

attributes	Q	n	Crocodile Physics 402				Edison4			
			r	a	sd	%				
Attributes relating to the interface	42	54	15,0	25,59	3,5	61	15,0	24,6	3,6	59
Attributes relating to its use as a material in education	23	54	16,0	13,20	3,8	57	13,0	12,4	3,2	54
Attributes relating to virtual lab programs as a Product and Service Support	14	54	8,0	8,2	2,2	59	9,0	9,3	2,2	66

Q: number of questions; n: number of participants; r: range; a: average; sd: standard deviation

**Table 5.** The standard deviation relating to evaluation scores

	<b>n</b>	<b>r</b>	<b>a</b>	<b>sd</b>
Crocodile Physics 401	54	28,0	47,0	6,4
Edison4	54	29,0	46,2	7,4

n: number of participants; r: range; a: average; sd: standard deviation

As can be seen from Table 5, Crocodile Physics 401 received an average score of 47,0 out of 79, and Edison4 46,2. In order to check the consistency of the evaluation, the results of the evaluations performed by the fifty four participants were analyzed in terms of the standard deviation and range values relating to the calculations.

### **Conclusion and recommendations**

In this study, the usability attributes required for virtual lab programmes used in physics lessons were converted into concrete and measurable attributes using three categories – attributes related to the interface; attributes related to the programme’s use as a material in education; and attributes related to product and service support – and a scale comprising 79 attributes was developed. The aim was for the scale to serve as a guide for the selection of a suitable virtual lab programme by students, teachers and school administration.

As a result of the usability evaluations performed on the basis of a full score of 79 points, the standard deviation is 6,4 for Crocodile Physics 401 and 7,4 for Edison4. This difference is considered to have arisen from the fact that the academics and teachers who evaluated the Evaluation Scale have different perspectives and skills in relation to the use of such programmes. It may be worthwhile to examine this situation with a group with broader participation.

The Evaluation Scale developed in this study can serve as a guide in the selection of a suitable virtual lab programme for teachers and education institutions who wish to use virtual lab programmes in order to achieve their



aims. Furthermore, the Evaluation Scale can act as a guide for students wishing to create experiment mechanisms and receive feedback relating to the experiments created.

Another important result observed in this study is the differences in the educationalists' skills in using virtual lab programmes. It is quite striking to observe differences even in the results obtained as a result of the evaluations based merely on Yes/No answers. Limitations have been experienced in finding individuals, who have used such software in lessons, are specialized in this field and capable of evaluating such software. It would be worthwhile to repeat the study with broader group of participants.

It is important to develop measurement tools so that educational software can achieve specific quality standards. Today, a limited number of virtual lab programmes contain a limited number of experiments suitable for a specific target audience. It would be highly beneficial to develop virtual lab programmes in line with developments in technology and education, and to update the Evaluation Scale accordingly.

The Crocodile Physics 401 and Edison4 programmes have been evaluated using the Evaluation Scale developed in this study. The evaluation of secondary education virtual lab programmes using the Evaluation Scale will aid companies developing such educational software during the design stage. This study was conducted based on the software used in a secondary education physics course. Conducting similar studies of other fields and levels is important in terms of the provision of access to evaluation scales for every field and level. Furthermore, it would be helpful to develop virtual lab programmes of a higher quality, and to determine requirements for their use in different fields and at different levels.

### *Limitation*

In Turkey, the experts who can evaluate and use effectively virtual lab programs are not many. This limits the work group to 54 people. Because of this limitation, factor analyzing in developed the Evaluation Scale could not be realized.

### NOTES

1. <http://www.useit.com/alertbox/20030825.html>
2. <http://www.l3s.de/web/upload/documents/jensen-imej04.pdf>

### REFERENCES

- Bateman, R.E., Bowden, R.G., Gogg, T.J., Harrell, C.R., & Mott, J.A. (1997). *System improvement using simulation*. Orem: ProModel Corporation.
- Budhu, M., & Coleman, A. (2002). The design and evaluation of interactivities in a digital library. *D-Lib Magazine*, 8, issue 11.
- Ezginci, Y., Güler, İ., Özbay, Y. & Altunkaya, S. (2006). Biyomedikal Laboratuvarı Eğitimine Multimedyalı İnternet Desteği. *Elektrik-Elektronik-Bilgisayar Mühendislikleri Eğitimi 3.Ulusal Sempozyumu*, EEB06, İstanbul, p. 22–25.
- Galanouli, D., Murphy, C. & Gardner, J. (2004). Teachers' perceptions of the effectiveness of ICT-competence training. *Computers & Education*, 43, 63–79.
- Gündoğan, M. B. (2003). Kullanılabilirlik (Usability) Kavramı ve Eğitim Teknolojileri; Yansımalar, Uygulamalar. *Proceeding of International Educational Technologies Symposium and Fair, I*, 642–649.
- Gustavsson, I. (2002). Remote laboratory experiments in electrical engineering education. *Proceedings of the 4th IEEE International Caracas Conference on Devices, Circuits and Systems, Aruba*, I025-1–5.

- Guzzi, R., Scarpanti, S., Ballista, G. & Di Nicolantonio, W. (2005). An educational development tool based on principles of formal ontology. *Educational Technology & Society*, 8, 80–89.
- Harrell, C. R. & Tumay, K. (1995). *Simulation made easy: a manager's guide*. Norcross:: Industrial Engineering and Management Press.
- Jeschke, S., Richer, T. & Zorn, E. (2001). *Virtual lab*. Berlin: DFG Research Center Matheon.
- Keyhani, A., Marwali, M.N., Higuera, L.E., Athalye, G. & Baumgartner, G. (2002). An integrated virtual learning system for the development of motor drive systems. *IEEE Transactions on Power Systems*, 17, 1–6.
- Levine, T. & Donitsa-Schmidt, S. (1998). Computer use, confidence, attitudes, and knowledge: a causal analysis. *Computers in Human Behavior*, 14, 125–146.
- Lin, P. I., Broberg, H. & Mon, A. (2002). A web-based lab for distance learning. *ASEE Annual Conference Proceedings*, pp. 10161-10172.
- Malloy, T. & Jensen, G.C. (2001). Utah virtual lab: JAVA interactivity for teaching science and statistics on line. *Behavior Research Methods Instruments & Computers*, 33, 282-286.
- Nikoukaran, J., Hlupic, V. & Paul, R.J. (1998). Criteria for simulation software evaluation. *Proceedings of the Winter Simulation Conference*, pp. 399-406.
- Noor, A.K. & Wasfy, T.M. (2001). Simulation of physical experiments in immersive virtual environments. *Engineering Computations*, 18, 515–538.
- Özdener, N. (2004). Deneysel Öğretim Yöntemlerinde Benzetişim (Simülasyon) Kullanımı, *Proceedings of 4th Congress of International Educational Technologies*, 1, 239-343.

- Potosky, D. & Bobko, P. (2001). A model for predicting computer experience from attitudes toward computers. *J. Business & Psychology*, 15, 391–404.
- Rozell, E.J. & Gardner, W.L. (1999). Computer-related success and failure: a longitudinal field study of the factors influencing computer-related performance. *Computers in Human Behavior*, 15, 1–10.
- Scherp, A. (2002). Software development process model and methodology for virtual laboratories. *Proceedings of the 20th IASTED International Multi-Conference 'Applied Informatics' (AI 2002)*, Innsbruck, Austria, pp. 47–52.
- Serra, M., Wang, E. & Muzio, J.C. (1999). A multimedia virtual lab for digital logic design. *Proceedings of the IEEE International Conference on Microelectronic Systems Education, 19-21 July 1999*, pp. 39–40
- Sanchez, J., Dormido, S., Pastor, R., Morilla, F. (2004). A Java/Matlab-based environment for remote control system laboratories: illustrated with an inverted pendulum. *IEEE Transactions on Education*, 47, 321–329.
- Subramanian, R. & Marsic, I. (2001). *Vibe: virtual biology experiment*. Piscataway: Department of Electrical and Computer Engineering and the CAIP Center.
- Weissman, Z. & Yahel, R.Z. (1999). Communication courseware for college students. *Computer Physics Communications*, 121–122, 578–582.
- Williams, D., Coles, L., Wilson, K., Richardson, A. & Tuson, J. (2000). Teachers and ICT: current use and future needs. *British J. Educational Technology*, 31, 307–320.

✉ Özden Karagöz, E-Learning Specialist  
E-Mail: [ozdenkar@gmail.com](mailto:ozdenkar@gmail.com)

Dr. Nesrin Özden  
Ataturk Faculty of Education,  
Marmara University, Turkey  
E-Mail: [nozdenner@marmara.edu.tr](mailto:nozdener@marmara.edu.tr)