Innovations

Computer-aided Instruction for C++ Programming and its System Usability Scale Score

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Abstract

Application of Information Technology in the evolving and advancing field of education has been a great help to academic institutions in enhancing and strengthening teaching and learning. In this study on computer-aided instruction (CAI), efforts were exerted to develop a computer-based application that could be used as a support in teaching basic C++ programming. Such an effort is driven by the continuous demand to improve the quality of education amongst higher education institutions (HEIs) in the country. Specifically, this study intended to provide a mechanism for the electronic delivery of lessons and monitoring of student's learning progress. It also covered the assessment of the system's level of usability. Structured analysis served as the development strategy. The final output was then evaluated for usability by its intended users which include Information Technology (IT) faculty members and students from the University of Eastern Philippines. A number of IT faculty members from other schools also served as respondents. Results showed that the system was able to deliver the lessons with the use of the specified hardware and software and that student's learning progress was tracked continuously. Based on the evaluation, the e-learning tool has an above-average level of usability, which implies that it could be used as an adjunct in teaching and learning basic C++ programming.

Keywords*: Blended learning, Computer-aided instruction, E-learning tool, System Usability Scale*

I. Introduction

Computer-aided instruction (CAI) does help in the teaching and learning process. The study of Chen et al., (2023) stated that CAI enhances the way people understand things like concepts and theories. It promotes teaching efficiency and can increase student's interest in studying. It also provides students with the benefits of learning with the use of multimedia. Aside from these, the need for CAI is also triggered by several other important reasons. According to the work of Januszewski and Buchalska-Sugajska (2022) and Seker(2013), the increase in the use of computers in education is the result of the rise of the student population, amount and complexness of information, teacher and student ratio, time scarcity, and the variance among the students' ability and personality. As such, higher education institutions (HEIs) have been doing their best in strengthening both teaching and learning processes by employing the power of technology to keep pace with the demands in education and that of the labor market as well.

In the study of Al-Badi and Khan(2022), it was found out that although HEIs have shown interest and have spent resources in the employment of technology in its processes, they still have to do more to fully realize the

potential of technology as strong support to the teaching-learning process. As in the case of a university here in the Philippines, although their delivery of instruction already includes IT influences (e.g., computer network, computer applications, internet, email, LCD TV, data projector), it still needs to strengthen more its use of technology to enhance instruction further. And that was identified by the Accrediting Agency of Chartered Colleges and Universities in the Philippines during one of its visits to the concerned university.

With all the foregoing statements, the researchers deemed it necessary to get involved and contribute by aiming to develop a computer-based application based on CAI that could be used as a support in teaching a particular introductory programming course, i.e., basic C++ programming.

The rest of the paper is organized as follows. Section 2 presents the objectives of the study. Section 3 shows and explains the methodology applied in constructing the e-learning tool. On the other hand, section 4 discusses the assessment conducted on the said tool and the corresponding results. Section 5tackles the conclusion of the study.

II. Objectives of the Study

This study aimed to develop a computer-aided instruction for C++ Programming. Specifically, it sought answers to the following:

- To provide mechanism for the computerized delivery of lessons;
- To monitor the student's learning progress; and
- To assess the e-learning's tool level of usability.

III. Methodology

The following subsections explain and/or illustrate the different details pertaining to the development of the e-learning tool. This includes the technical background, requirements analysis, and design of the e-learning tool.

A. Technical Background

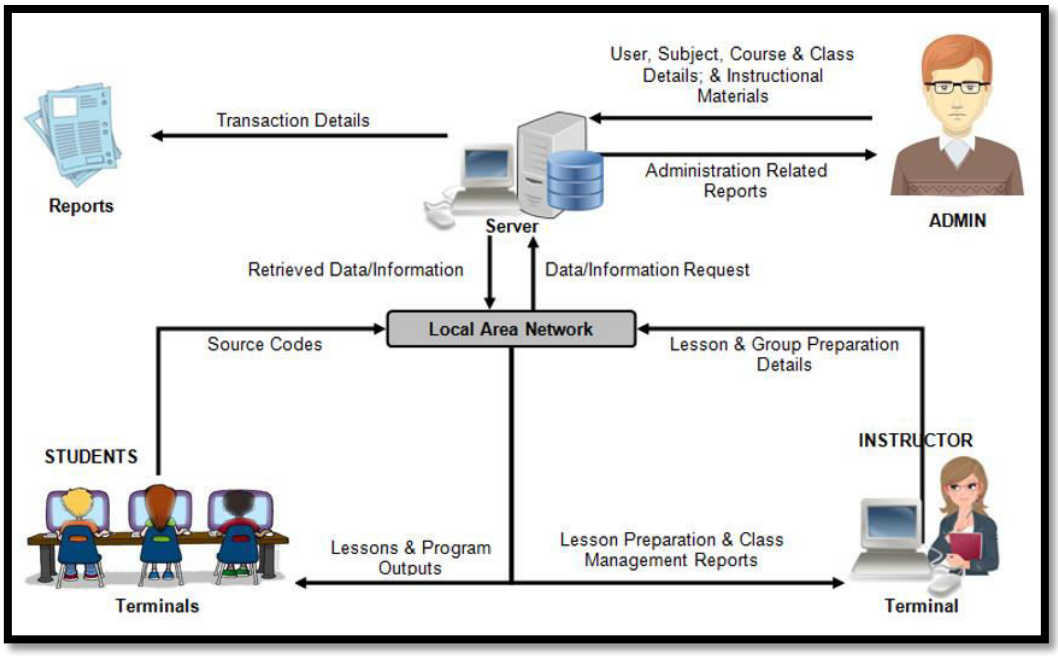

Figure 1. System Architecture

Figure 1 shows how the hardware, software, data, and people that are involved with the application software are organized for a specific business goal, i.e., to make teaching and learning of basic C++ programming possible. The e-learning tool which is a desktop application requires a local area network that connects the desktop computers used by the students and the instructors, and the server which houses the database and all the resources needed. We can see in this figure that the administrator manages and controls the relevant data and information that are required for the system to be able to operate successfully. Part of that is inputting into the server the necessary technology-based learning materials (i.e., lessons in the form of text, audio, video, or pdf) coming from the instructor who is basically the one who creates and assigns learning materials to corresponding lessons. These materials are kept on the hard disk and are organized through the database. They are logically presented to the students during instruction. Meanwhile, the student undergoes learning through the instructional materials provided beforehand. The student can also write programs and have the corresponding outputs shown and this is to let them apply the concepts and techniques taught through the e-learning tool which furthers their learning experience. All the transactions of every participant (e.g., instructor, student, admin) are stored for the generation of essential information or reports.

B. Requirements Analysis

The researchers conducted a series of informal interviews with several faculty members of the IT Department of the College of Science, University of Eastern Philippines – the first state university in the Visayas. By doing so, the fundamental concept of this study was crafted, and the system requirements were discovered and completed. To make the application software more useful and relevant, the researchers had to also do literature and studies review which had helped immensely in gaining the correct understanding of the system (its nature and functions). It also revealed unknown ideas and facts that should form part in the requirements. Furthermore, it is important to note that the interviews done with the IT faculty members (i.e., programming instructors) facilitated the verification of the requirements of the system.

The gathered requirements were organized and turned into a list of system requirements which include both functional and non-functional requirements. This served as the source and basis of the application software's functions and processes.

C. Design of a Computer-aided Instruction for C++ Programming

The logical models presented in this subsection are some of the blueprints for developing the system. These models including the system architecture presented earlier may display a combination of any of the following: data, people, functions, and processes. Their meaningful organization describes what the system can do and provide.

Before designing any CAI software or system, its exact purpose must be determined first to identify the type of CAI system it should be. Also, according to Yu-bao et al., (2010), having a good grasp of CAI's principles (e.g., suitable application, suitable information, combining traditional teaching with modern teaching) and enough understanding of its assistant role are both related to its effect and quality and therefore these must be taken into consideration. In this work, the e-learning tool was intended to augment the traditional delivery of instruction by offering the instructor an alternative teaching strategy to use should he/she find applying it suitable and necessary depending on the need or situation.

Figure 2 shows the context diagram which depicts the application software as a single process together with the actors interacting with it and their respective primary data or information of interest. These actors or external entities include the instructor, student, and administrator. In this diagram we can see that the administrator must input first into the system the: class list so that the students can gain access to the system; and the instructional materials so that the instructors can assign them to their respective lessons. The instructor, meanwhile, is the one who adds a new lesson (record) into the system with the use of the instructional materials input by the administrator beforehand to form the C++ e-lessons (i.e., electronic lessons). Assuming that all such lessons have already been added, the student now avails himself/herself of said e-lessons. As he/she progresses, the lessons taken are recorded (see Figure 6). Using such data, the system generates the 'taken lessons report' which the instructor uses to know the study progress of each student. Finally, all the actions taken by all types of users are being recorded and the data for this is used to generate the 'user activities report' which the administrator utilizes for auditing. The rest of the processes, data flows, and data stores are hidden within process 0. This diagram is only meant for giving us the bird's eye view of the system and thus we only can see the primary data flows.

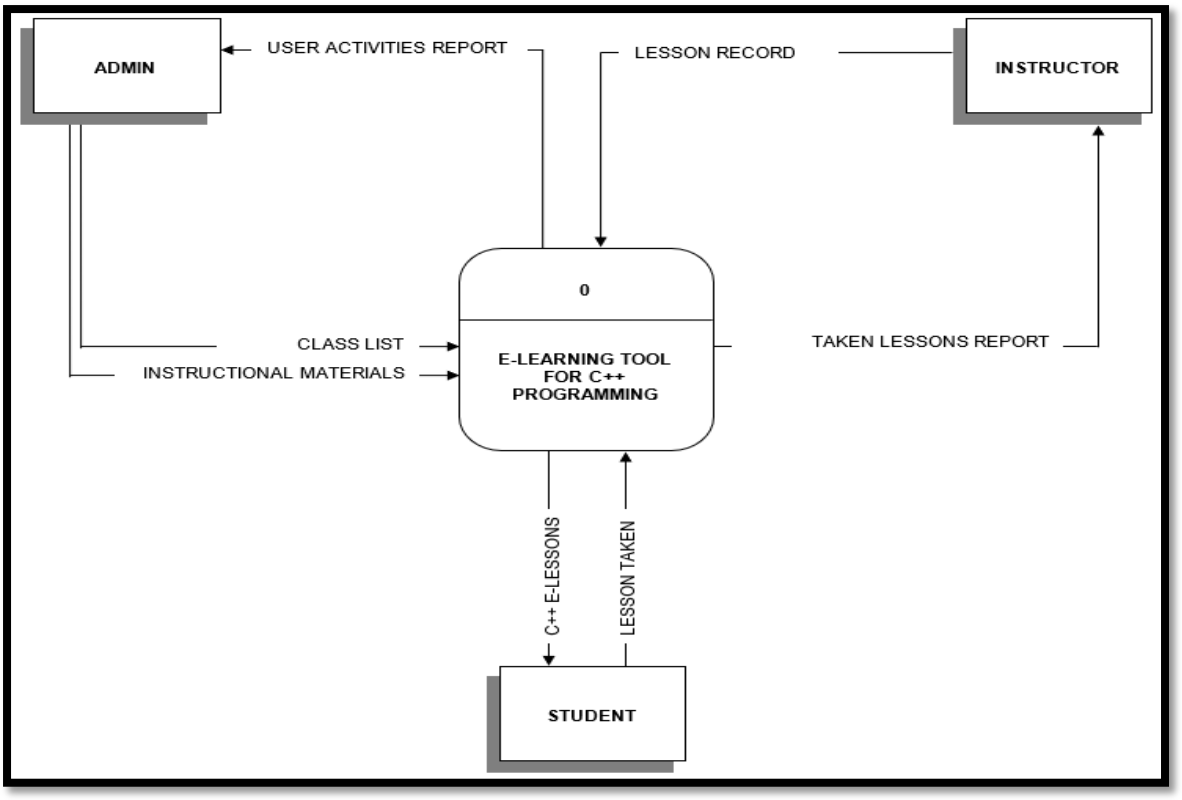

Figure 2. Context Diagram

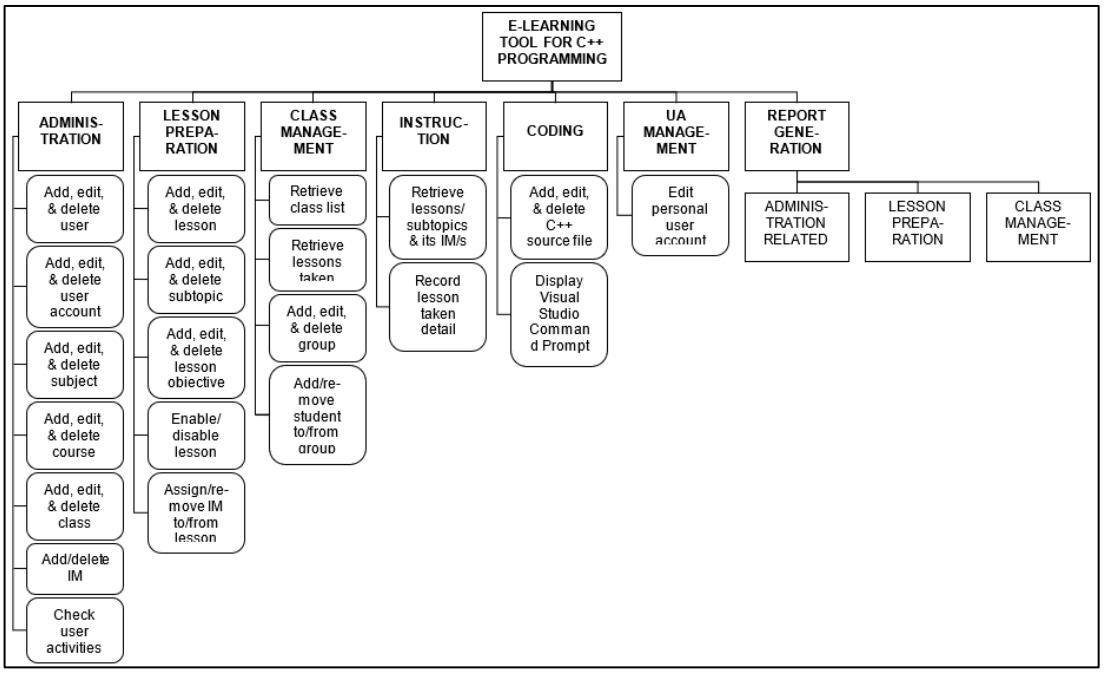

Figure 3. Functional Decomposition Diagram

Figure 3 shows that the application software provides seven major functions. Below each major function is either its sub-functions or its processes. The first six major functions (i.e., administration, lesson preparation, class

management, instruction, coding, user account management) display their respective process/es beneath them which detail/s the specific task/s that must be performed by the system. Meanwhile, the last major function (i.e., report generation) has three sub-functions whose respective process/es underneath is/are no longer shown but whose details are specified as follows: a) the administration related report includes the users list, subjects list, students list, and the log of user activities; b) the lesson preparation report includes the lessons list and lesson objectives list; and c) class management includes the taken lessons list. All these functions and processes are based upon the systems requirements formulated during the planning and analysis phases.

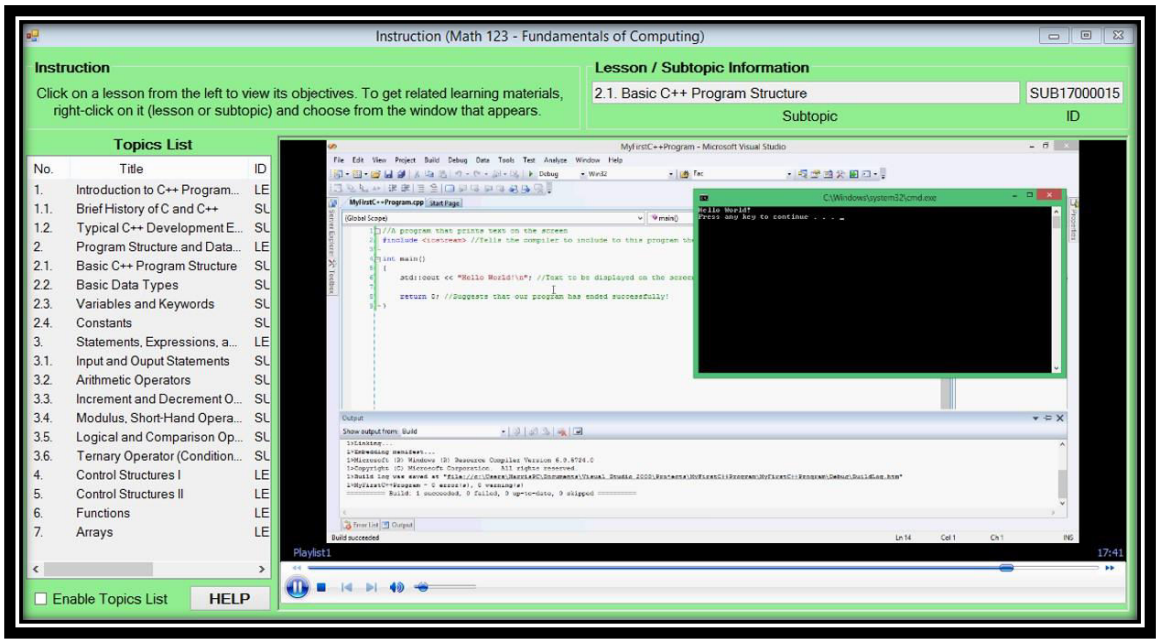

Figure 4. E-learning Tool Rendering a Lesson in Video Format

Aside from identifying the CAI system's exact purpose or role, essential considerations that focus on making it an effective learning tool must also be considered. Abersek & Abersek(2012) stated that an e-learning tool should not put aside the philosophical and didactical aspects as these are considered to be as important as the technological aspect, maybe even more. That is emphasized as well by Seo& Bryant (2009) declaring that the instructional principles and features embedded in CAI systems are the critical factors closely related to students' positive academic outcomes. Therefore, the teaching method must be considered and carefully incorporated and applied to an e-learning tool as it affects learning. According to Minyi et al., (2010), the design model of CAI indicates the teaching method or style used. These design models include the following: demonstrate/explain model, practice model, simulate/demonstration model, teaching game model, and computer assistant testing model. In relation to this work, the output of this study relates to the first two models mentioned. The e-learning tool was designed basically to deliver instruction by transforming the conventional way of explanation and demonstration into technology-based using multimedia. Text, audio, video (see Figure 4), and portable digital files are the forms of learning material that can be saved into and rendered by the system. Multimedia helps discuss the topics, especially the difficult ones, more effectively than just by using speech only. Moreover, the tool also helps students practice programming by allowing them to write computer programs. The system calls the development command prompt of Visual Studio whenever the need for compiling and running the written program arises (see Figure 5). As for the teaching method or style, it lies in the hands of the learning material creator (i.e., instructor) as the e-learning tool only provides an avenue to systematically deliver the learning materials (fed to it) to the students during class time.

Cai et al., (2012)mentioned that a good CAI software should not be concerned only on the teacher's tasks and presentation of lessons. It should also be interactive to offer students the chance to think and comprehend. Also, teachers and students must be able to run and control the entire learning process and even reorder it illogically. In

this study, the system that was developed is a lecture-based one (i.e., it delivers inputted programming lessons), but which was somewhat like a tutorial since the programming lessons fed to it could be tried or practiced by the students as the system allows them to write computer programs (see Figure 5). As for the control of the lesson's progression, it is shared by both teacher and student. The teacher can reorder, enable, and disable lessons to control which lesson to focus upon. The student, on the other hand, is given the liberty to study any lesson remaining enabled which means that apart from the lesson at present, he/she could study in advance any future lesson or go back to any past lesson.

Finally, Chaudhari (2013) discussed that before using the system, the learning area where students are having problems must be discovered first, then determine if CAI is needed for it. Next, if CAI is required, form the objectives related to the problems. Lastly, create the right learning material for it with the use of appropriate software. In this work, the creation of such content is not involved. The e-learning tool works by being fed with the learning materials that it would present, which must be intelligently and carefully prepared by the instructor because it is the most essential part of the system that directly influences the students' learning outcomes.

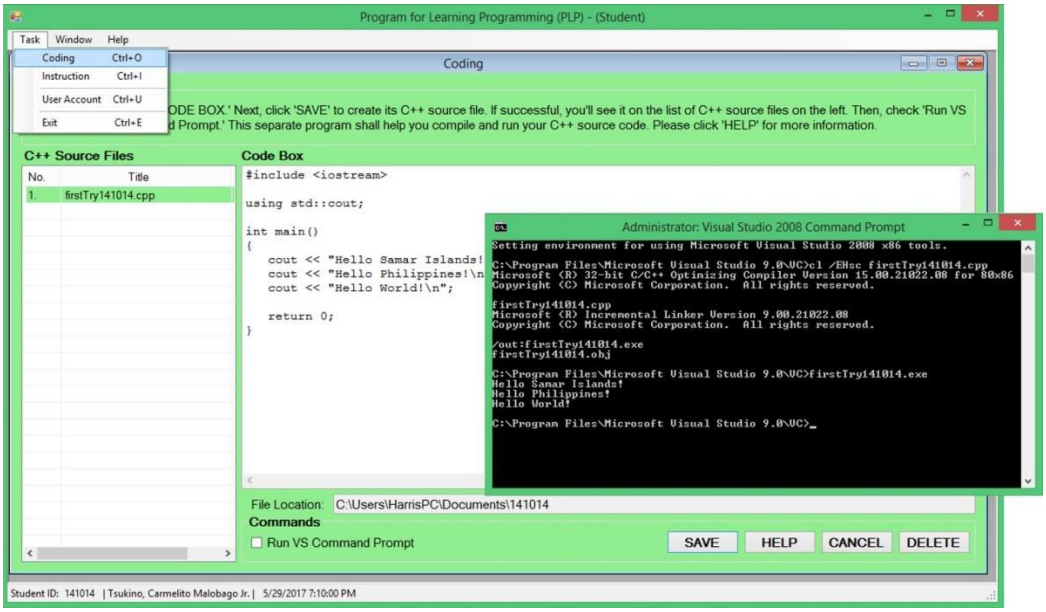

Figure 5. E-learning Tool's Coding Practice Feature

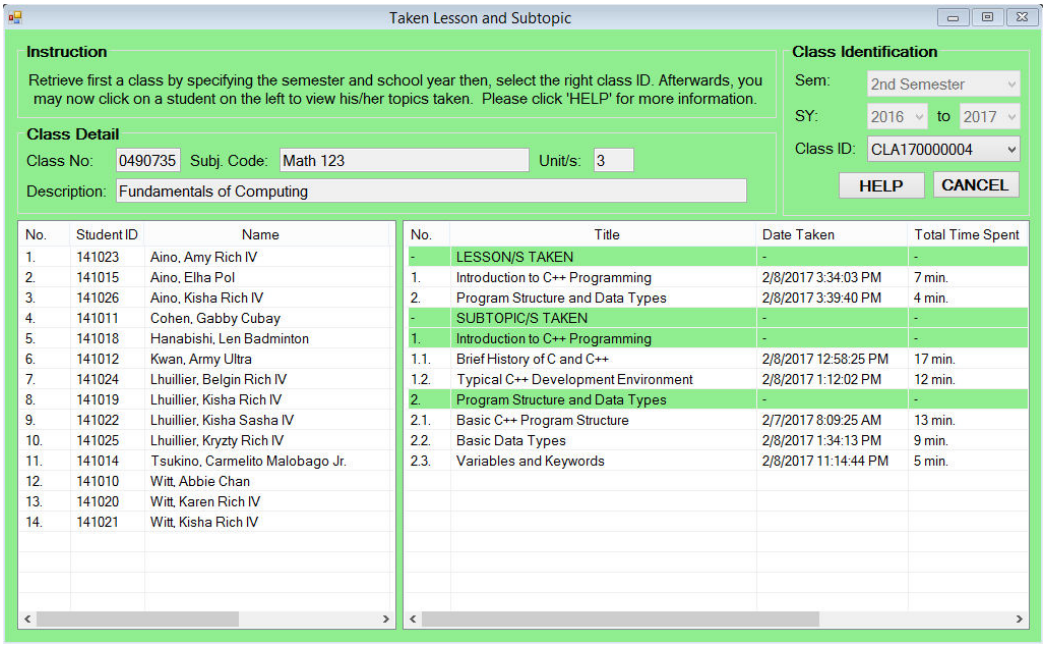

Figure 6. E-learning Tool's Learning Progress Monitoring

IV. Results and Discussion

The e-learning tool's usability was evaluated by thirty (30) IT faculty members coming from the University of Eastern Philippines and other nearby higher education institutions and, thirty (30) IT students from the same university. The age of the respondents who participated in this usability test ranged from 16 to 45 years old. Usability, according to Chua & Dyson (2004), refers to the system's capacity to be comprehended quickly, learned to use easily, used without much effort, and its attractiveness.

The instrument utilized that is called System Usability Scale which is discussed in the work of Brooke (1996), is a scale that consists of ten (10) statements providing an overall view of the subjective assessment of usability. Each statement is given a score of 1 (suggesting strong disagreement) to a score of 5 (indicating strong agreement). These statements, however, are uniquely created. Odd-numbered statements are expressed in the positive. On the contrary, even-numbered statements are expressed in the negative. These varying statements have been originally arranged in an alternate fashion to prevent the respondents from giving a biased response or from answering without really reading and thinking about the statement.

To compute for the SUS score as explained by the author of the instrument, J. Brooke (1996), the scale contribution for the odd-numbered statements will be the scale position selected minus one. As for the even-numbered statements, it will be the chosen scale position subtracted from five. The resulting scale contribution (which ranges from 0 – 4) for each item will be summed up, and that sum will be multiplied by 2.5 so that the result is within the range of zero to one hundred (100) rather than zero to forty (40). The reason for that according to Brooke (2013) is, people would more easily understand the SUS score if it were within that range (i.e., 0-100).

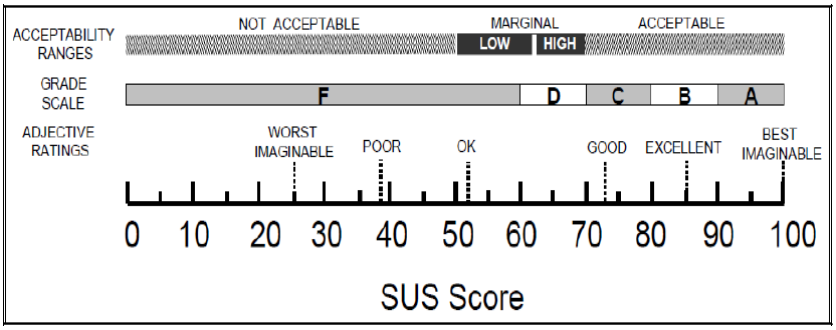

Figure 7. Basis for a More Meaningful Interpretation of the SUS Score

Note. This comparison of adjective ratings in relation to the average SUS score was produced by Bangor et al., in 2009.

In having the questionnaires answered, the student respondents were given a brief discussion on the purpose of the system, and a demonstration of its functions followed. Time was given for them to try using the prototype. The instructors, on the other hand, immediately tested the prototype and filled out the survey form. Afterwards, the questionnaires were gathered, and the data coming from them were tabulated, analyzed, and interpreted. As a result, we got two overall SUS scores, i.e., one for the IT faculty members and one for the IT students.

With the IT faculty members' evaluation, an overall SUS score of 75.83 was earned, which is higher than the mean SUS score of 68 (see Figure 8 and Table 1). Sixty-eight (68) is the average level of usability according to Sauro(2011). According to the same, an SUS score higher than that is considered above average, and anything below that value is below average. Therefore, this means that the e-learning tool has an above-average level of usability. And, based on Figure 7 by Bangor et al., (2009), the system is said to be acceptable, or 'good' in terms of adjective rating. In terms of grade scale, it has reached 'C' which means that the system is adequate but could improve. All in all, this suggests that faculty members found the system to be usable and could be applied in class.

With the IT students' evaluation, an overall SUS score of 73.17 was earned, which is higher than the mean SUS score of 68 (see Figure 9 and Table 2). Same as the previous one, the e-learning tool is found to have an above-average level of usability. And, based on Figure 7, the system is said to be acceptable or 'good' in terms of adjective rating. As with the grade scale, the system has reached 'C' which means that it is adequate but could improve. All in all, this suggests that students found the system to be usable and could be applied in class.

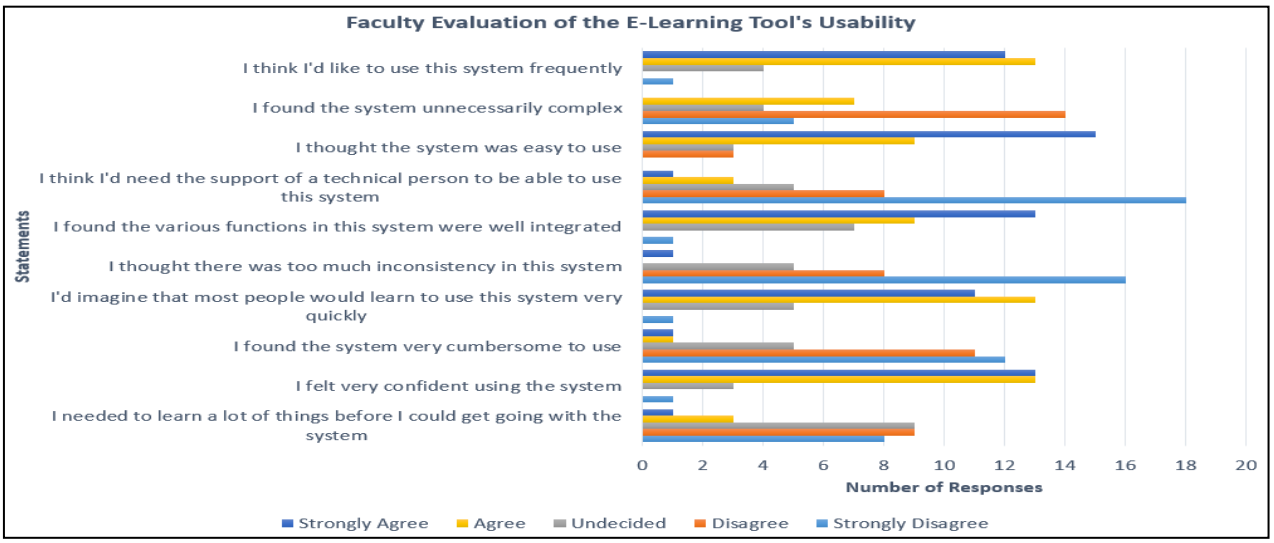

Figure 8. System's Usability Evaluation by Faculty Members

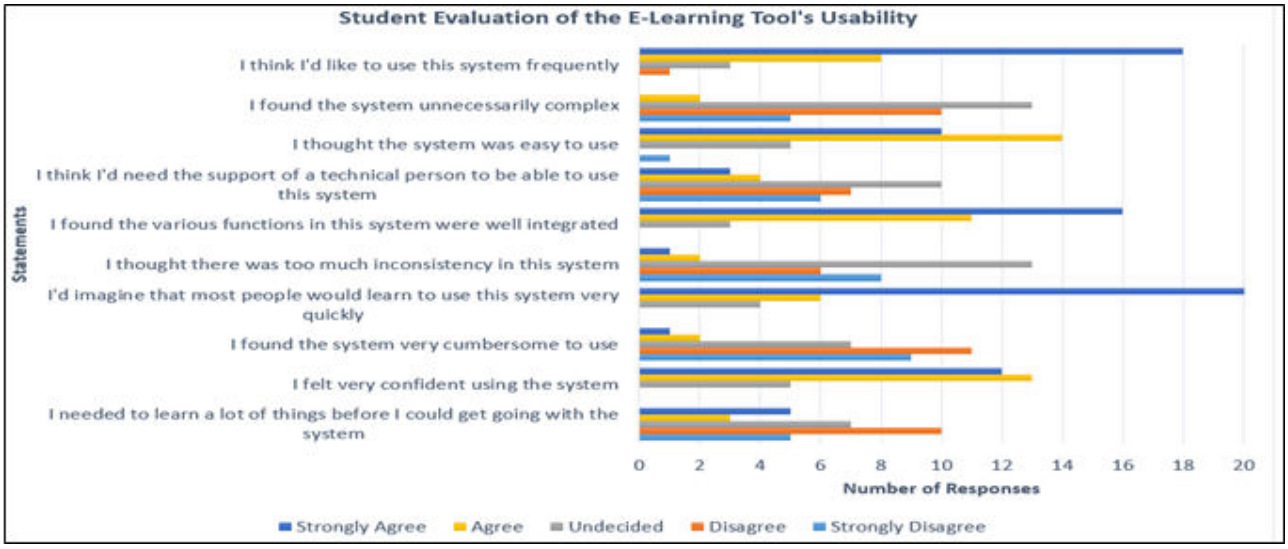

Figure 9. System's Usability Evaluation by Students

Table 1: IT Faculty Usability Evaluation of the E-learning Tool

Statement	Count of Scores				
	SD	D	U	A	SA
1. I think that I would like to use this system frequently.	1	0	4	13	12
2. I found the system unnecessarily complex.	5	14	4	7	0
3. I thought the system was easy to use.	0	3	3	9	15
4. I think that I would need the support of a technical person to be able to use this system.	13	8	5	3	1
5. I found the various functions in the system were well integrated.	1	0	7	9	13
6. I thought there was too much inconsistency in this system.	16	8	5	0	1
7. I imagine that most people would learn to use this system very quickly.	1	0	5	13	11
8. I found the system very cumbersome to use.	12	11	5	1	1
9. I felt very confident using the system.	1	0	3	13	13
10. I needed to learn a lot of things before I could get going with this system.	8	9	9	3	1
Overall Average SUS Score:			75.83		

Note. SD-strongly disagree; D-disagree; U-undecided; A-agree; SA-strongly disagree; N = 30

Table 2: IT Students Usability Evaluation of the E-learning Tool

Statement	Count of Scores				
	SD	D	U	A	SA
1. I think that I would like to use this system frequently.	0	1	3	8	18
2. I found the system unnecessarily complex.	5	10	13	2	0
3. I thought the system was easy to use.	1	0	5	14	10
4. I think that I would need the support of a technical person to be able to use this system.	6	7	10	4	3
5. I found the various functions in the system were well integrated.	0	0	3	11	16
6. I thought there was too much inconsistency in this system.	8	6	13	2	1
7. I imagine that most people would learn to use this system very quickly.	0	0	4	6	20
8. I found the system very cumbersome to use.	9	11	7	2	1
9. I felt very confident using the system.	0	0	5	13	12
10. I needed to learn a lot of things before I could get going with this system.	5	10	7	3	5
Overall Average SUS Score:			73.17		

Note. SD-strongly disagree; D-disagree; U-undecided; A-agree; SA-strongly disagree; N = 30

V. Conclusion

The developed e-learning tool adhering to its hardware and software specifications was found to be efficient in performing its critical tasks. Should it be provided with carefully planned and prepared e-learning materials, and utilized appropriately, it can bring positive effect on the students' learning of basic programming in C++. As an adjunct to the traditional way of teaching, it can also be used to promote independent learning among the students, and this will pave the way for the teachers to become more of a mentor than an instructor within the classroom as the focus would shift from giving lessons or instructions to giving advice, guidance, and further elaboration of the things learned since the instruction task is already handled by the e-learning tool. In addition, monitoring of student's learning progress was useful in promoting student's curricular development. And finally, with the tool's usability testing result that is above the marginal or average level, this application was found to be highly usable in teaching the introductory programming course.

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