



# An Interactive Learning Environment for Information and Communication Theory

Mohamed Hamada  
University of Aizu, JAPAN

Mohammed Hassan  
University of Aizu, JAPAN

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## ABSTRACT

Interactive learning tools are emerging as effective educational materials in the area of computer science and engineering. It is a research domain that is rapidly expanding because of its positive impacts on motivating and improving students' performance during the learning process. This paper introduces an interactive learning environment for teaching and learning information and communication theory and related courses. The environment integrates several modules to meet the students' different learning styles. It contains a movie-like module, an animated hypertext introductory module that fully explains the fundamental concepts of information and communication theory. Besides those important learning modules, it also contains a self-assessment module that contains a set of interactive tests and examinations. Learners can use the environment as a standalone application or as an applet from within any web browser. Some evaluation experiments and comparative analyses of the results were performed to measure the performance of our environment in the classroom.

**Keywords:** Interactive Learning; Learning Technology; Virtual-learning Environment; Information and Communication Theory.

## INTRODUCTION

One of the most significant discussions regarding advances in hardware and software is their ability to support interactive learning tools that can enhance the learning process and their potentials to support learning requirements of an individual learner.

The term interactive learning tool is commonly referred to a computer-based environment that integrates a group of learning modules such as audio, video, animations, simulations, graphics, text, etc. They enable students to experience their learning topic in an easy and expressive manner. Interactive learning systems have become a common practice in computer engineering education, and it received a considerable critical attention. (Boluda et.al, 2006; W. Chen, 2007; Haffner, 2006; Hamada & Sato 2006; Mohamed., 2008; Hamada, 2007;

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**Correspondence:** Mohamed Hamada, *University of Aizu, Ikkimachi, 965-8580 Aizuwakamatsu, Japan.*

✉ [mhamada2000@gmail.com](mailto:mhamada2000@gmail.com)

### **State of the literature**

- Students attend classes and taught in one group irrespective of their learning preferences.
- Many professors teach their students theoretically in some courses that require students' participations to better understand the subject.
- Most of the existing literatures that developed an interactive learning environment for information and communication theory did not cover the entire course/subject; they only focused on some selected topics.

### **Contribution of this paper to the literature**

- This paper introduces a complete design and use of an interactive learning environment for computer science and engineering courses. It aims to contribute to this growing area of research in the interactive learning environment by exploring the concept of information and communication theory and related courses. The environment was developed and tested on students taking this course for three consecutive years. The understanding and performance of the students were improved when using this learning environment.

Martinez-Jimenez et.al, 2006; Li, 2006; Rodger, 2006; Cadenas, 2015) are some of the recent examples of interactive learning environments. In these learning tools, hypertexts, graphics, animations, and simulations are widely used. Most of these studies have shown that using interactive learning systems can improve the learning outcome and enhance the students' motivation. However, while designing an interactive learning environment, considering students' learning styles will serve as a catalyst in improving the effectiveness of the system.

A considerable number of literatures have been introduced (e.g. (Herman, 1990; Felder, 1988; Kolb, 2014; Briggs Myers, 1980; Hamada, Muhammed, & Tufan, 2014) in order to realize the learning preferences of students. Among them, the simpler and easier to implement (see (Felder & Spurlin, 2005)) is Felder-Silverman (Felder & Spurlin, 1988). It classifies learners into 4 groups, just as sequential vs. global, visual vs. verbal, sensing vs. intuitive, and active vs. reflective. Logical steps and sequential details are the basis for sequential learners to understand concepts. Global learners prefer to understand a concept as a whole and in big jumps. Diagrams, images, demos, movies, and tables are the preferred learning methods of visual learners. Written and spoken words are the best learning methods for verbal learners. Sensing learners try to understand concepts using their several sense organs. Intuitive learners try to understand concepts by discovering facts and the relationships that connect them. Active learners understand concepts through the idea of "I do, I learn". Reflective learners tend to think about facts as a preferred method of learning. In (Rosati, 1998), an empirical study of the Felder-Silverman model was reported in order to specify what kind of learning preferences that engineering students possess. The result of this study outlined that engineering students tend to have visual, sensing, sequential, and active learning preferences.

Nonetheless, previous studies on interactive learning have not paid much emphasis on students' learning preferences. Therefore, in this research, we proposed to develop and

evaluate an interactive learning environment that takes students' learning preferences into consideration in learning the concept of information and communication theory.

The concepts of information and communication theory have a very wide range of practical applications. Owing to its abstract nature, these concepts are normally taught by using classroom lectures in a usual style, which makes studying such concepts a less motivating task for engineering students (because of their strong active learning preferences). Our interactive learning framework is developed mainly to deal with this problem and give supports to engineering students especially those with active learning preferences. The proposed environment is suitable for supporting active learners in information and communication theory topics, and also in many other related fields some of which are: image processing, data compression, telecommunications, error detection and correction courses, etc. Such topics cover a variety of concepts, like communication channels, coding/decoding techniques, source of information, techniques for detection and correction of errors, mutual information, source entropy, etc. The modules of the system are implemented in Java and then integrated into a unique environment that uses Java2D interface (Java2D of Sun Microsystems). The system is web-based, very portable, with a rich and easy to understand interface that has many desirable properties for motivating students towards learning. These characteristics make our environment a useful interactive learning tool for engineering students that can provide them with an opportunity to advance their understanding of the target subjects.

In developing our environment, we paid special attention to the learning model of active constructionism (Hadjerrouit, 2003; Perkins, 1996) and the principles of its design, which includes:

- 1) Learners should act as knowledge constructors, not as passive receiver from teachers
- 2) The learning process should contain embedded assessment procedures that consider learners' individual orientations.

Benefits of using interactive learning systems in computer engineering education, includes, but, of course, not limited to the following:

- Allow using more brain sensors, which in turn will encourage deep reflective thinking.
- Allow creating an enhanced learning process for individual learners.
- Allow learners to behave as designers by using computer simulations to analyze their topic.

The overall structure of the paper takes the form of seven sections, including this introductory section. Section two of the paper discussed some related works. Section three is concerned with the introduction of our interactive learning environment and all of its modules. The learning theory that provides a theoretical basis for our system will be discussed in section

four. Section five examines the results of our experiments. Discussions of research findings are presented in section six. Lastly, section seven of the paper contains the conclusion that summarizes our findings and areas for future work are discussed.

## RELATED WORK

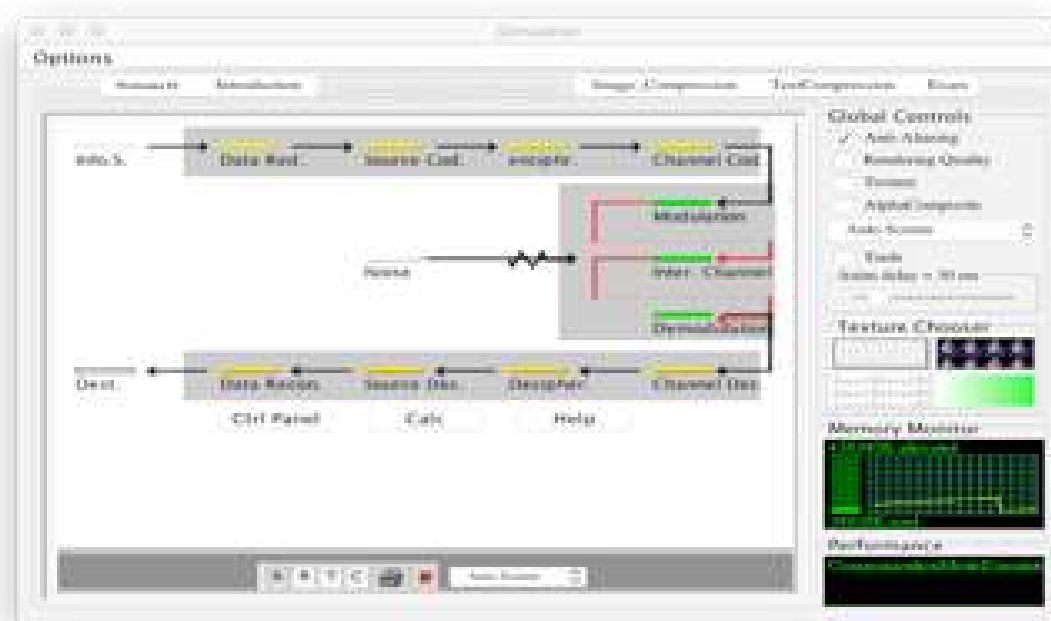
Based on our intensive search, and the use of many keywords, with several search engines such as MSN, Google, Yahoo, and Wikipedia, but so far, no previous work that develops a similar single tool for the entire area of information and communication theory course. However, little attention has been paid to develop a system that can simulate just one topic in information and communication theory. For example, a number of authors (Ang; W. Chen, 2007; Ligus; Thanh) have introduced a simple simulation of the Huffman coding. In comparison with the Huffman algorithm simulation of our system (that represents only one of the many modules in our system), we found that this new system is more educative and interactive than all of them. In these Huffman's code simulations, learners can only (passively) watch a simulation of how Huffman algorithm works. While in our learning environment, learners are able to build the coding steps one-by-one or as a whole. This provides a more interactive learning environment and makes students more engaged in the learning process. In addition, they can obtain an immediate and a direct assistant at any stage during the learning session by navigating on the "introduction" module or simply by clicking on either the "Help" or the "Hint" button.

In (Mackay), a collection of information theory simulation programs was introduced such as Huffman, Hamming, and arithmetic coding. Unlike our all-in-one simulation, they are written as separate programs in different programming languages such as TCL, Python, and C. So they need a separate compilation and execution. Hence, they are not portable and need more efforts from the user (to run and use them) than our environment. In addition, our environment is more interactive and allows the user to get more engage in the simulation process rather than just sit and watch in a passive style.

## INTERACTIVE LEARNING ENVIRONMENT

For the purpose of integrating different desirable components of the subject, the interactive learning environment is designed to have six different modules, which are assembled into a unified user-friendly interface to enable the students to access all the modules in an easy way. The modules are as follows: First, is an animated (movie-like) welcome module that briefly introduces the environment to the learner. Second, is a hypertext introduction module that introduces the basic concepts of information theory (in a power point presentation style to make it easily accessible by learners), three simulation modules: a communication model simulator, an image compression simulator, and text compression simulator. Finally, an assessment module that contains a set of self-assessment tests designed carefully to assess the learners' performance during the learning process. The "welcome" and "introduction" modules are designed to match the sequential learning preferences of students. The

simulators' modules are more suitable for students with sensing and active preferences (such as engineering students). The environment is implemented in Java and integrated into Java2D. It is worth mentioning that using Java2D as an interface for the environment can enhance the visual clarity of the contents and can add extra functions like texture change, memory monitoring (as shown in the right side of [Figure.1](#)), and a possibility for printing from within the environment (as shown in the bottom side of [Figure.1](#)). In the sequel, we will introduce all the system's modules. Subsection 3.2 is based on our previous work (Hamada, 2007b).



**Figure.1**

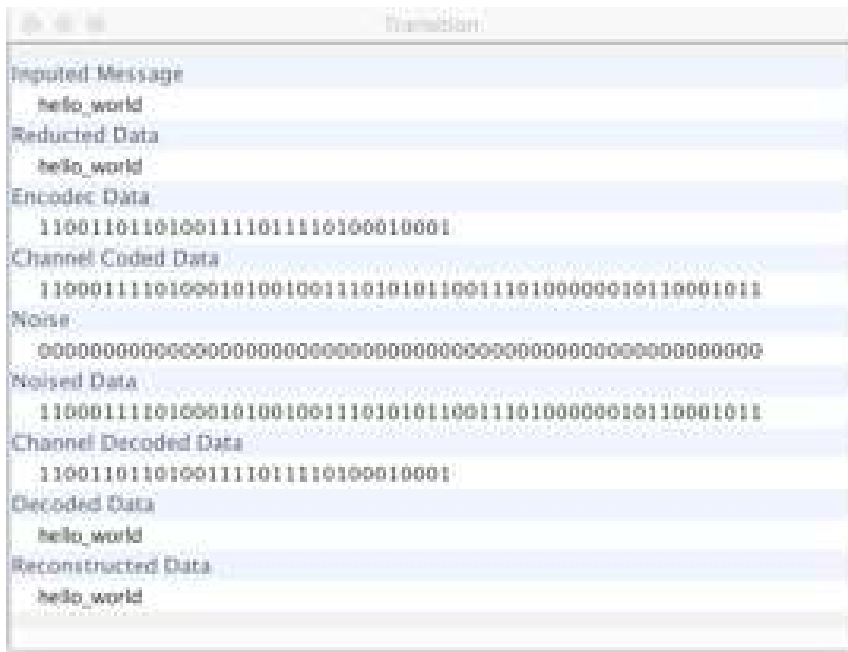
### **Welcome and Topics “Introduction” Modules**

The first two modules of the learning system are dealing with the basic concepts of information and communication theory. One module introduces a movie-like simple introduction of the course. The second one introduces an intensive “introduction” in a hypertext format that uses a PowerPoint presentation style. Students can easily use the hyperlinks in this module as a navigation method through the course concepts. An audio narration is combining the presentation in order to make it easier for students who may have some difficulties in reading the text. It also can support students with audio/visual preferences. The introduction also is available in both English and Japanese as a bilingual presentation.

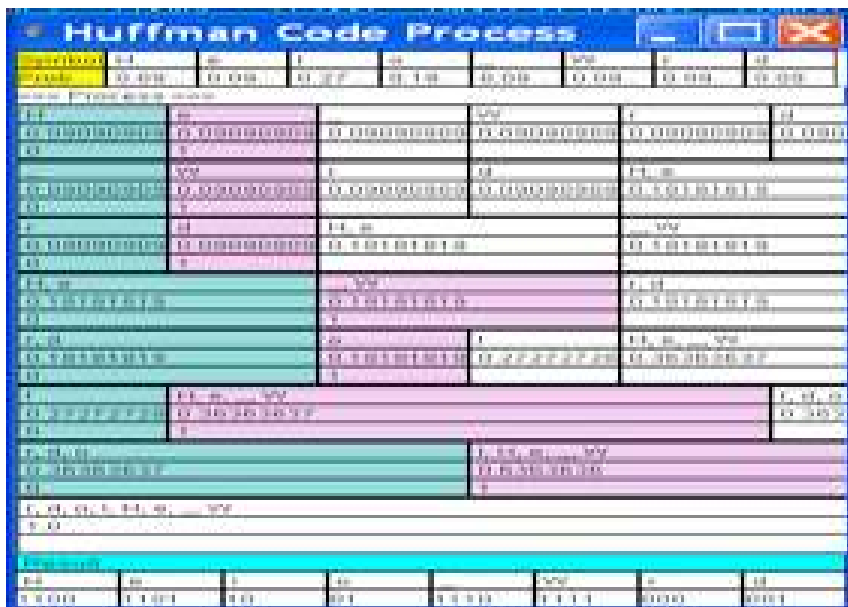
### **Simulator for the Communication Model**

This section introduces the simulator for the basic communication model. It simulates the basic operations that describe the steps of message transmission from source to destination.

**Figure.1** shows an overview of interface of the simulator, which is based on our previous work (Hamada, 2007).



**Figure.2**



**Figure.3**

Therefore, more detailed description of the simulator can be found in (Hamada, 2007). **Figure.2** and **Figure.3** present the snapshots of the simulator working on an example that

simulates the transfer of the message “Hello World” (Figure.2) using Huffman coding technique (Figure.3).

### Image Compression Simulator

The image compression simulator is concerned with a bitmap (.bmp) image format. It can compress a bitmap (.bmp) image using several image compression techniques such as 8-bits, 8-bits with run length code (RLE), 16-bits, and 24-bits. Bitmap compression technique was chosen because of its wider area of applications. For built-in graphics subsystems, many graphical user interfaces use bitmaps; See, for example, the OS/2 platforms' GDI subsystem and Microsoft Windows. Also, many other image formats, such as PNG, JPEG, GIF, and TIFF uses bitmap format.



Figure.4

The image compression simulator interface is set out in Figure.4. To facilitate the learning process, there are several additional functions namely: make image, test, and help were integrated into the simulator. The help function gives a comprehensive introduction to the image compression simulator, its underlying algorithms, and its use. It is useful for new users as a learning starting point. It is given in bilingual (English/Japanese) with easy to use hyperlinks to each learning object. The “Make Image” function in Figure.5 below can help learners to understand “how images can be created from a group of pixels”. First, the learner can set the desired width and height of the images he wants to create. Next, select the desired bitmap algorithm (like 8-bits, 8-bits (RLE), 16-bits, or 24-bits) to create the image. Based on the given width  $w$  and the height  $h$ , a set of empty squares ( $= w * h$ ) will appear as provided in Figure.5 above. The learner can then fill in the empty squares with hexadecimal values for each pixel or can use the “Random” button to randomly fill in the values for all pixels. Finally, the learner can use the “Make Image” button to create the corresponding image. The “Clear” button can be used to clear the squares and start the creation of a new image.

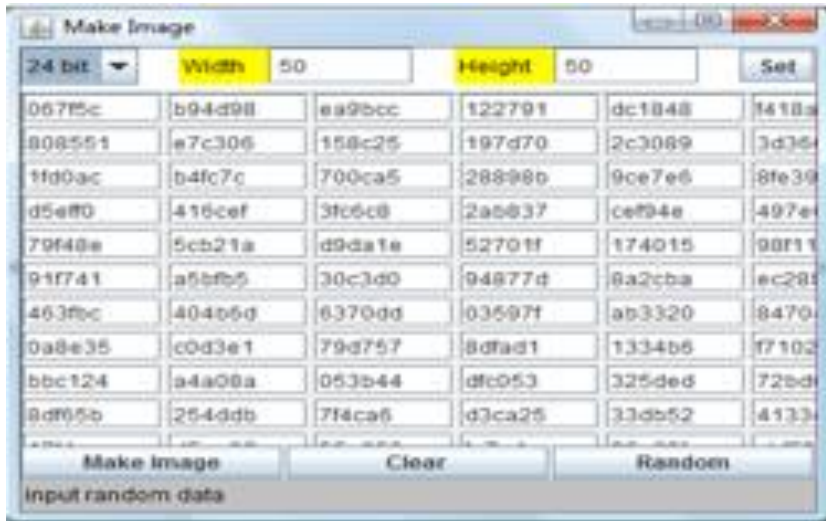


Figure.5

By clicking on the “Load” button in the main image in the simulator interface, the user can load a bitmap image that he/she wants to convert into another bitmap representation. The loaded image and its information will appear in the upper area of the image simulator window (See Figure.4 for an example of a loaded 24-bit bitmap image). In the shown example, since the loaded image is in 24-bit format, the “24-bit” button will be disabled and the other buttons (“8-bit”, “8-bit (RLE)”, and “16-bit”) will be enabled. By clicking on one of these three enabled buttons (for example “8-bit (RLE)” button as in the example of Figure.6) the loaded image will be transformed (compressed) into the corresponding format. The compression result will be shown in the lower area of the simulator window as displayed in Figure.6.



Figure.6



In addition to the resulting image and its related information, two other windows will appear automatically, one window will give a detailed result of the image pixels, the other window will give detailed values (in decimal and hexadecimal representations) of the image colors (the color of each pixel) included in the compressed image as summarized in the example of **Figure.7** below.



Index	Dec. value	Hex. value	Color
[0]	218, 197, 178	da, c5, b2	
[1]	217, 198, 177	d9, c4, b1	
[2]	220, 200, 176	dc, c8, b0	
[3]	216, 196, 176	d8, c3, b0	
[4]	218, 199, 174	da, c6, ae	
[5]	243, 235, 239	f2, eb, ef	
[6]	243, 239, 238	f2, ef, ee	
[7]	244, 240, 237	f4, f0, ed	
[8]	221, 201, 177	d9, c9, b1	
[9]	241, 232, 235	f1, eb, ef	
[a]	219, 198, 179	db, c6, b3	
[b]	245, 240, 241	f5, f0, f1	

**Figure.7**

The test function is important for helping learners to understand the underlying bitmap image compression algorithms. When the learner clicks on the “Test” button, a pop-up window, showing the underlying algorithms, will appear. The learner can select the desired algorithm she/he wants to learn. For example selecting “24-bit to 16-bit” a new window will appear as in **Figure.8**. First, the learner will be asked to input (in the text area) the RGB (Red, Green, Blue) values for the 24-bits image that she/he wants to convert to 16-bits. A set of empty colored (Red, Green, Blue) squares will appear (see **Figure.8**). Every line represents the inputted data with different representations. The “Hint” button can be clicked at any time to give quick information about what the student should do at this moment and how she/he can do it. The student can also click on the “Random input” button to get a quick random example. By clicking on the “OK” button, the student can check her/his result. If the student still cannot get the correct answer, then she/he may click on the button “Answer” to get the correct answer automatically.



Figure.8

### Text Compression Simulator

The text compression simulator is concerned with Lempel-Ziv (LZ) text compression algorithms. A. Lempel and J. Ziv introduced the lossless data compression algorithms LZ77 and LZ78 in 1977 (Ziv and Lempel, 1977) and 1978 (Ziv and Lempel, 1978) respectively. They are the foundations for many other LZ variations, such as LZW, LZSS, LZMA, etc. LZ methods do the data compression by replacing multiple occurrences of data with some references to one copy of the data that exist earlier in the initial data stream. The matching process is encoded with a double of numbers known as “length-distance” numbers. To place matches, the encoder has to keep the reference of some quantity of the most recent information, for example, the final 2, 4, or 32 kB. The framework in which this information held is known as a “sliding window”, that is the reason for calling the LZ77 the “sliding window” compression.

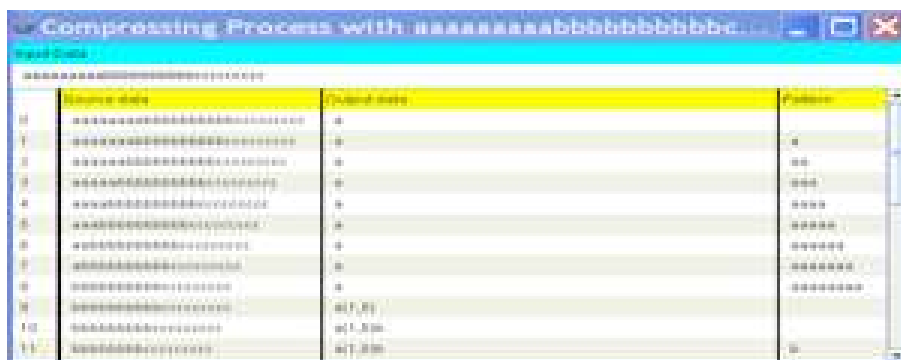
We decided to adopt LZ compression techniques because of its practical importance. Some applications of LZ compression techniques are GIF, TIFF, V.42 bis modem compression standard, PostScript Level 2, and the well-known ZIP format for data compression.

**Figure.9** shows the main interface window of the text compression simulator. The learner can either input text (to be compressed) directly into the text input area (in the upper part of the simulator) or load a text file (using the “Load” button) to compress it. The “Clear” button can be used to clear the current data and start a new text compression session.



**Figure.9**

A comprehensive hypertext help window will appear when the user clicks on the “Help” button. This help window will give a detailed information about the underlying LZ compression algorithms and a detailed information about how to use the text simulator. An example of inputted text is illustrated in [Figure.9](#). After inputting the text, a typical session of using the text compression simulator is as follows. The learner can set the desired “sliding window compression” value using the slide bar (located along the right side of the simulator window). The learner can now start to compress the inputted text by clicking on the “Compress” button. Then the detailed compression process of the inputted string will appear in a separate window as it appears in [Figure.10](#) for an example. The figure shows the source data, the output (compressed) data, and the compressed pattern, are given in a step-by-step format. This allows the student to go through deep details of the LZ compression algorithm.



**Figure.10**

Similarly, learner can also input a compressed text (or load a compressed file) and click on the “Decompress” button to decompress it. Then the decompression process will appear in details (in a separate window).

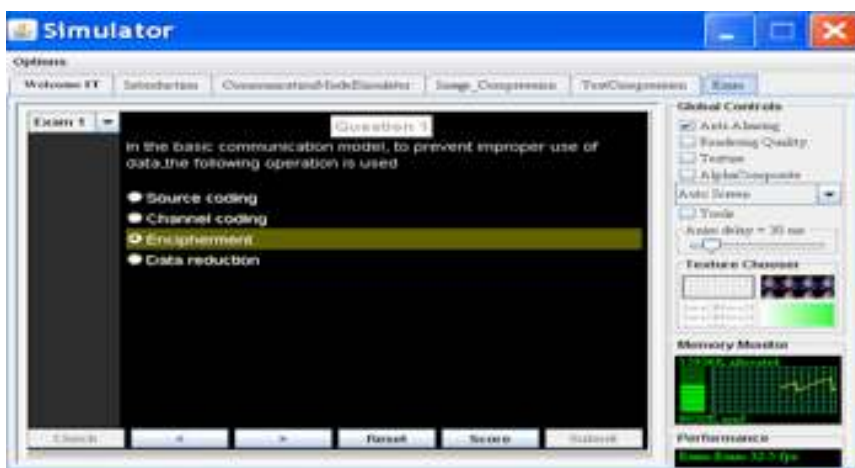
The test function is important to help the learner to understand the underlying LZ compression algorithms. When the learner clicks on the “Test” button, a pop-up window, with several options, will appear as given in [Figure.11](#). The learner can set the desired “sliding window compression” value using the slide bar. Next, the learner will be able to input some text in the “In” area (stands for input). Then she/he can try to write the output in the “Out” area (stands for output). If the inputted text was compressed, then the output text should be its uncompressed version and vice versa. The student can check her/his answer by clicking on the “Compress test” or the “Decompress test” buttons. If the student cannot make the correct answer, she/he can try to click on the “Hint” button to get a quick comment that may help in finding the answer. Otherwise, she/he can click on the “Compress data show” or “Decompress data show” buttons to get the correct answer automatically.



**Figure.11**

### The Learners' Assessment Module

A selected group of tests with increasing level of difficulties is integrated into the system. It contains many kinds of questions such as multiple choice, fill in the blank, etc. Students can try the tests before, during, or after the learning sessions. [Figure.12](#) shows the assessment module's interface.



**Figure.12**

When the student selects a proper test from the interface window, the test description will appear (e.g. its level, its prerequisites' knowledge, its objectives, method of evaluation, etc.). Using the navigation buttons, students can go through the list of questions. Students can also check their current score at any time throughout the test. During a quiz answer, students may get some help by clicking on the "introduction" button to get more readings on the courses that are related to the question.

## LEARNING THEORY

It is not always bad to think on which learning theory is preferable than the other, but however, using an integrative approach is more important than arguing on the preferred learning theory. This is because; such approach can integrate several instructional methods that are necessary to effectively promote the students' learning preferences. For instance, literatures such as (Gagne, 1985; Merrill, 1983; Mudur, 2005; Reigeluth, 2013) contain the following instructional design issues for content design.

- Classification of knowledge.
- Sequencing of content.
- Developing the required learning outcome and learning events.

Therefore, by taking these principles into account, we developed our learning environment. The methodological approaches taken in the design process of our environment are well explained in the following subsections.

### Learning Design

The study uses learning design because of its representation of new possibilities for improving the quality of the learning process within an e-learning environment (Britain, 2004). Two things to note here are:

- Learning design (LD): The advantage of LD is that students learn in a better way if they are engaged in some learning activities.
- Learning activities (LA): LA should be designed carefully in a workflow of learning to facilitate the effectiveness of learning.

Following these ideas and the IMS-LD learning design specifications (IMS-LD Learning Design Specifications) and (The Advanced Distance Learning Group; Dougiamas, 2002), our environment is designed from a set of learning objects and a set of learning activities described below.

### *Objects*

The following environment's modules describe the learning objects.

- 1) The first learning object is the "Topics" component (represented by the "Welcome" and "Introduction" modules). This is a collection of URLs and PowerPoint presentations that describe the course concepts. Students can navigate through these concepts sequentially or can select a specific concept from the main menu through the hypertext links.
- 2) A collection of examples that reflect the use of the information theory concepts in our daily life. The main purpose of these examples is to motivate students by showing them the relevance of the topics. Students can study these examples and see how they are connected with the theoretical topics.
- 3) The communication model simulator is the learning object that enables the learners to interactively build a communication process (from source to destination) and test how it works in a detailed sequential order.
- 4) The image compression simulator is the learning object that facilitates the students to learn how the image can be created and encoded. This can help to deepen their understanding of the corresponding theoretical aspects of the subject.
- 5) The text compression simulator is the learning object that helps the students to learn how text can be compressed and decompressed. This also can help to deepen their understanding of the corresponding knowledge.
- 6) A group of tests is a learning object that helps them to assess their learning progress. The tests are of different levels, starting from general and easy tests to more specific and difficult ones. Students can try to answer the tests at any time during the learning session.

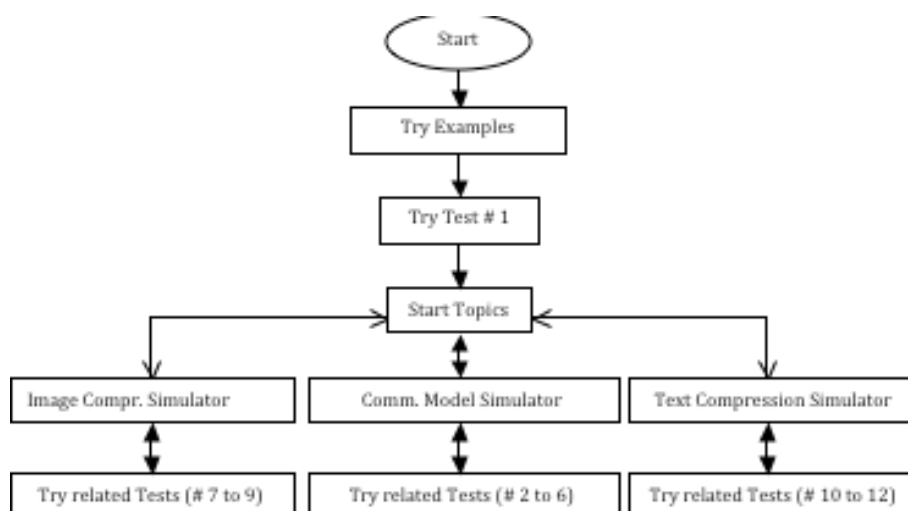
### *Activities*

Based on our several years of experience in teaching information and communication theory, we recommend students to respect the following sequence of learning activities.

- 1) Students are recommended to start by reading the examples in the introduction module. At this level, a prior knowledge of the information theory concepts is not necessary. This step may attract the students' attention on how the subject is relevant to our daily activities. The attention of the students and relevance of the subject are among the principles of the ARCS model of motivation developed by Keller's (Keller J. M., 1987).
- 2) Trying to answer some of the (easy) assessment tests, students can gain self-confidence, which is also one of the principles of Keller's ARCS motivation model (Keller J. M., 1987). By now, students should be ready to start studying the theoretical aspects of the subject through the topics modules.

- 3) Therefore, students are now ready to try using the simulators. While using the simulators, students are recommended to switch to the theoretical topics (in the topics module) for proper understanding. While reading a certain topic, students are also recommended to try the appropriate simulator and design a model for the concept they study and test it with different input data. Such learning practice can be useful to deepen the knowledge of the students and improving the learning progress.
- 4) For self-assessment (while they read the concepts and use the simulators), students are encouraged to take the related test. Hence, their confidence on the learning process can be upgraded.

The learning objects and a suggested workflow of the learning activities through the system are given in [Figure.13](#).



**Figure.13**

## EVALUATION

Several experiments were performed to evaluate the effectiveness of our learning system towards students' motivation and performance. Motivational experiment was prepared and carried out according to Keller's ARCS motivational model (Keller J. M., 1987). An alternative experiment was carried out to evaluate the students' performance when using our environment. For the purpose of estimating how students enjoyed this application, students' feedbacks about the environment were collected and analysed. Lastly, a statistical survey on the students' grades in the past five years was carried out for analysis and comparison.

### Motivation

Motivation plays a vital role in inspiring learning activities and enhancing the learning process. A number of motivational models have been developed, such as ARCS model (Keller J. M., 1987), Intrinsic Motivations (Malone, 1987), and Time Continuum Model of Motivation

and Motivational Framework for Culturally Responsive Teaching (Wlodkowski, 1999). Among these models, ARCS model has been used to evaluate motivations of learners in a variety of learning settings, including E-learning environments and web-based distance settings (Keller J. a., 2004), hypermedia contexts (Carson, 2006), and classroom face to face setting (Small, 2004). Therefore, this model has been used in this study as a measure for students' motivation. ARCS model is based on four factors, namely, attention, relevance, confidence, and satisfaction. In this paper, the word Attention will be used to refer to the gaining and sustaining learners' attention in a learning environment and can be reinforced through some learning practices such as perceptual arousal (where gaining attention can be achieved by offering novel and surprising activities). The term Relevance referred to the degree that instructions meet learners' needs and could be achieved through "familiarity" by adapting instruction according to learners' background. Confidence is the expectancy of the learners for success and could be achieved through "success opportunities" (providing different achievement levels), and "personal control" (providing feedback and support). Finally, Satisfaction was referred to learners' feeling about their accomplishments and could be enhanced by providing "natural consequence" (providing opportunities to use newly acquired knowledge in a real or simulating setting), and "positive consequences" (providing feedback and reinforcement).

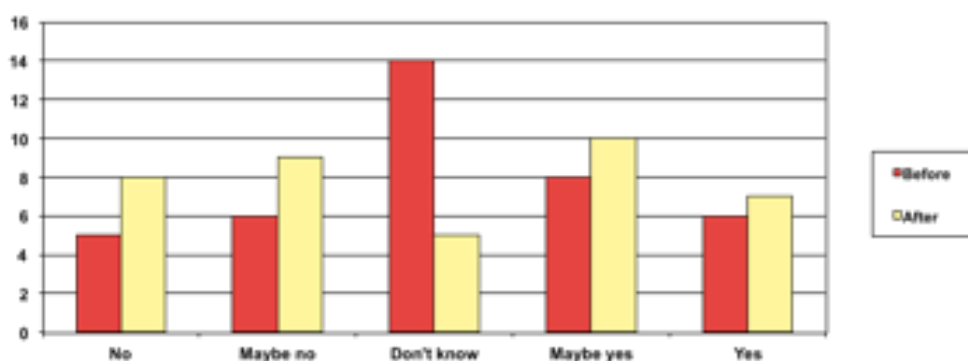
The four factors of the ARCS motivational model were the basis for designing our environment. As for attention, a set of different attractive materials such as videos, simulators, hands-on examples, etc., were integrated into the environment. These active materials also matched with the active learning preferences of engineering students (Rosati, 1998) to form the "familiarity" basis for the relevance part of ARCS model. The multilevel "test" component of the environment gives a chance for success to answer quizzes irrespective of the learner's level. This can offer some degree of confidence to the learners satisfying the relevance part of ARCS model. As for the satisfaction part of ARCS model, our environment provides a suitable platform to simulate the acquired knowledge through its several simulators and hence provide a "natural consequence" of the learning process.

To measure the effectiveness of our environment on the students' motivation, an experiment was carried out in the information theory classroom. A total of seventy-eight students were divided into two equal groups (experimental and normal) with 39 students each. Both groups attended the class regularly. However, in addition to their class attendance, the experimental group used the environment as an additional learning tool. By the end of the semester, a quantitative survey (based on ARCS model (Keller J. M., 1987) and on the study in (Kebritchi, 2008)) was conducted. The interaction methods of the survey (shown in [Table 1](#)) were adapted from (Kebritchi, 2008) where the validity and reliability were confirmed (based on Cronbach's alpha measure). The survey was conducted twice for each group, before and after completing the class. Students can respond using one of the following 5 options: "no", "yes", "maybe no", "maybe yes", and "don't know". The feedbacks of the normal group are shown in [Table 2](#) and [Figure.14](#).



**Table 1.** Survey quizzes based on ARCS motivational model.

<b>Attention</b>	There is something interesting about this class that will capture my attention.
	I believe this class will gain and sustain my interest.
	I think that the variety of materials, exercises, illustration, etc., will help keep my attention on this class.
<b>Relevance</b>	It is clear to me how this class is related to things I already know.
	I believe that the information contained in this class will be important to me.
	It is apparent to me how people use the information in this class.
<b>Confidence</b>	I think this class will be challenging, but neither too easy, nor too hard for me.
	As I learn more about this class, I am confident that I could learn the content.
	After working on this class for a while, I believe that I will be confident in my ability to successfully complete all class assignments and requirements.
<b>Satisfaction</b>	I believe that completing this class will give me a feeling of satisfaction.
	I believe that I will enjoy this class so much that I would like to know more about this topic
	I will really enjoy completing assignments for this class.

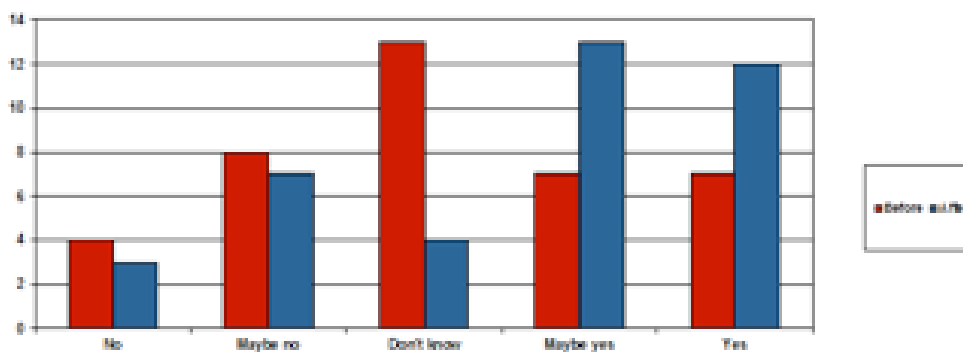
**Figure.14****Table 2.** Responses from Normal group students.

<b>Before</b>					
Answer	No	Maybe no	Don't know	Maybe yes	Yes
Average no. of students	5	6	14	8	6
<b>After</b>					
Answer	No	Maybe no	Don't know	Maybe yes	Yes
Average no. of students	8	9	5	10	7

It is clear from the table that majority of students in the normal group answered “Don’t know” before taking the class. After taking the class, and things became clearer, the “Don’t know” students are distributed almost equally in both sides “Yes” and “No”. We noticed that there was no significant difference in the students’ motivation towards the class. The responses of the experimental group are shown in [Table 3](#) and [Figure.15](#).

**Table 3.** Responses from the Experimental group students.

Before						
Answer	No	Maybe no	Don't know	Maybe yes	Yes	
Average no. of students	4	8	13	7	7	
After						
Answer	No	Maybe no	Don't know	Maybe yes	Yes	
Average no. of students	3	7	4	13	12	

**Figure.15**

As in the normal group, it is clear from the table that the majority of students in the experimental group answered, “Don’t know” before taking the class. After taking the class, and things become clearer, the “Don’t know” students are mostly shifted towards the “Yes” side. This shift indicates a considerable amount of improvement in the students’ motivation. It is also worth mentioning that the class attendance rate of the experimental group of students was higher than that of the normal class attendance. This is another indication that confirms increase in motivation among the experimental group of students.

### Performance

Using our environment as shown by the following experiment can enhance the students’ performance. To distinguish between two possibilities (using and not using the environment), a sample of one hundred students from the information and communication theory course was divided into four groups with twenty-five students in each group. Inter-group communications were highly restricted. Among the groups, only two groups were asked to study selected topics using the environment for a period of one month. The other two groups were asked to study the same topics within the same period without using the environment. However at the end of the month, each group received 10 out of 40 selected exercises to answer within a specific amount of time. A better performance from the groups using the environment was observed. Exercises were redistributed among the groups for a second round of the experiment. This was repeated by maintaining the groups in four rotations. In each rotation,

the performance of the two groups that studied the topics using the environment was better. In the average, at each time of the performance evaluation, those groups using the environment can approximately achieve 79% of the correct answers while the other students (studied without the environment) could achieve 51% of the correct answers.

### Poll

A Simple opinion poll was carried out to test suitability and usability of our environment as an active learning tool for information theory class. A mixed random sample of 180 students from the last three academic years (2012-2013, 2013-2014, and 2014-2015) when the environment was integrated into the course materials gave us their feedback through answers to the poll's questions.

Among the ten poll's criteria are questions related to the environment's functionality, design, simulators usability, and how it can help in enhancing the information theory learning process. Students were asked to evaluate the environment, based on these criteria, on a scale of five points: 0 to 4 (from worst to best). The average points for each item are shown in **Table 4**.

**Table 4.** Evaluation result of the environment

<i>Evaluation Items</i>	<i>Average Evaluation Point</i>
Design	3.8
User Friendly	3.7
Functionality	3.8
Communication model simulator usability	3.6
Image compression simulator suitability	3.2
Text compression simulator suitability	3.4
Suitability of provided tests	3.3
How it can help your IT learning process	3.4
The environment made me think beyond of the scope of the class	3.2
Overall evaluation	3.5

The collected data revealed that many items get a high evaluation. Generally speaking, students appreciated the environment as an active learning tool.

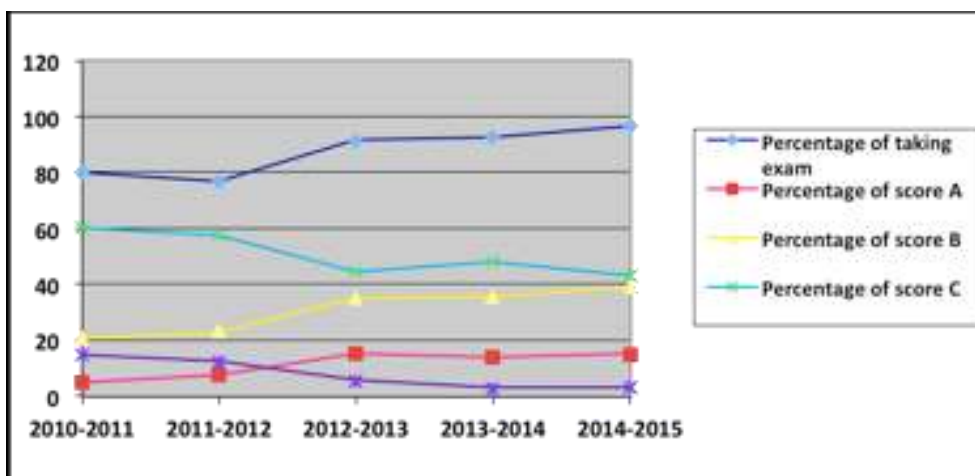
### Statistics

To measure the effectiveness of using the environment on the students' performance, a survey for the students' results on the last five years was carried out. The summary statistics for the survey presented in **Table 5** clearly reflects the positive effect of integrating our learning environment with the information theory course.

**Table 5.** Students' grades for five years

	2010-2011 Without the environment	2011-2012 Without the environment	2012-2013 With the environment	2013-2014 With the environment	2014-2015 With the environment
<b>Percentage Students taking the final exam</b>	79.8%	76.6%	91.4%	92.4%	96.5%
<b>Score A</b>	4.8%	7.3%	15%	13.7%	14.9%
<b>Score B</b>	20.5%	23.2%	35%	35.6%	39.2%
<b>Score C</b>	60.2%	57.3%	44.6%	48%	42.9%
<b>Failed (D and F)</b>	14.5%	12.2%	5.4%	2.7%	3%

The course evaluation is based on regular exams, homework, and learning sessions. In two academic sessions 2010-2011 and 2011-2012 before integrating the environment into the course, we observed that the number of failed students (graded D and F) is 14.5% and 12.2% respectively. In the academic year 2012-2013, the environment was integrated into the course. We observed a reduction on the number of students who failed the course. At the same time, an increase in the number of students with high scores (A and B) was observed. During the academic year 2013-2014, an improved version of the environment was integrated into the course. This results in a better performance in that academic year and the subsequent one (2014-2015). Therefore, it is interesting to note that in all the three academic years of this study, there was a significant increase in the number of students taking the course and writing the final exam, and the failures are decreasing drastically. Moreover, another single most striking observation to emerge from the result of our study is the percentage of students did not only pass the course, but also obtained very promising grades. [Figure.16](#) provides a graphical representation of the results.

**Figure.16**

From the data in **Table 5**, we can figure out the following improvement in the students' performance and motivation:

- 1) Number of students who dropped the course was reduced from 20.2% and 23.4% in the first two years (before integrating the environment into the course) to 8.6%, 7.6%, and 3.5% in the last three years consecutively (after integrating the environment into the course). This indicates that the students get more motivated and interested to study the subject.
- 2) Number of students with score A was more than doubled in the last three years compared with the first two years.
- 3) Number of students with score B was improved from 20.5% and 23.2% in the first two years to 35%, 35.6%, and 39.2% in the last three years consecutively.
- 4) Many students from the score C category are moved to score A or B category.
- 5) Number of failed students is dropped from 14.5% and 12.2% in the first two years to 5.4%, 2.7%, and 3% in the last three consecutive years.

## DISCUSSION

This research was set out with the aim of designing and assessing the impact of interactive learning environment for teaching and learning information and communication theory and related science and engineering courses. In this study, comparing result of using with that of not using the interactive environment in terms of students' motivations and their performance in the final examinations showed that the proposed method can make students to confidently register for the course and participate in the learning activities from beginning to the end of the course without thinking of whether to drop the course at the long run. Also their performance during the course examinations (**Table 4**) indicates that this new teaching method is more efficient than the traditional method. The finding further supports the idea of using other interactive learning tools such as interactive whiteboards (Lopez, 2010), interactive web-based tools (Cerra, 2014), interactive video (Kumar, 2010), or any visual representation approach (Abdullah et.al, 2014) in teaching and learning of science and engineering courses. Furthermore, not only the students will be happy with this recent development, research also shows that teachers on the other hand have a positive view of using interactive learning tools. The results observed in this research mirror those of the previous literatures (Dogru, 2014; Podschuweit, et.al 2016; Tanahoung et.al 2009) that examined the effect of introducing interactive learning environment at both secondary and tertiary institutions. One of the significant implications of this finding is that of improving students motivation towards learning and helping them to successfully pass their examinations with a high grades. It is important also to understand that learning preference is one of the instruments to be considered toward developing interactive learning environment, therefore further studies on related topics should try to integrate the environment with a means of testing the learning

preference of a learner. The system was tested for a long period of time through several consecutive semesters from 2010 to 2015. Hence the obtained data is more relatable.

Despite the positive side we prove in the research there is still few weak points. One of the weak points of the system is that it does not support the use of mobile devices that is getting more powerful, cheaper and at the same time more popular among young learners. This makes the system to be of limited use through only usual personal computers. Further researches on the current topic by extending the system to support mobile devices are therefore recommended. One more point that requires much attention is that the current system might not be suited for some learners specially learners with reflective learning preferences who prefer reading text more than the style of learning by doing. More investigation in this regard is needed and will be considered in future research.

## CONCLUSION

This research work was undertaken to design an interactive learning environment for teaching information and communication theory course and to evaluate its effect towards improving students' motivation and their performance in understanding the course and during the assessment tests and examinations. The environment was designed and can be used to assist students in understanding the course content using different learning and teaching methods. The evaluation was undertaken within three consecutive academic sessions, and the results were clearly presented both in tabular and graphical methods (**Table 5** and **Figure.16**). The relevance of the proposed environment in teaching information and communication theory is clearly supported by the findings of our experiments. The result of this research supports the idea that:

1. Students should be taught based on their preferred method of teaching (their learning styles).
2. The teaching for this course should be done from now on, using the proposed learning environment.

Moreover, in general, the most obvious finding to emerge from this study is that there is a need to integrate such learning environment in almost all computer science and engineering courses. An implication of following the result and suggestion we proposed above is the possibility that students performance will change drastically due to the high motivation they can gain through using such learning environment.

Finally, it is recommended that further research be undertaken when more modules and simulators are integrated into this learning environment, and perform more performance evaluation with a higher number of students and within a very long period of time.

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