

The Fourth Industrial Revolution based Innovation for Information and Communication Technology based Teaching

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Abstract: As we move into the Fourth Industrial Revolution Era, due to the massive development of the newest digital technology, our world is now so complex, interconnected, borderless and dramatically unpredictable. The demand from the borderless world is that critical and creative thinking skills are required for excellent communication, direct or indirect, real or virtual. The huge flow of information, which is so tremendous in the integrated system of globalized world, should be analyzed and synthesized carefully for the advancement of education and science. Information and knowledge in this era can be accessed through various mobile devices, using various available software and put in cloud computation storage easily. Place is no longer a barrier, as information and knowledge can be accessed under expanded networking services, from almost anywhere by almost any means. Information and communication technology-based teaching (ICT-based teaching), which covers digital and mobile learning, should be used as it is so important for students' life and career, and can give them critical and creative mathematical thinking abilities for selecting, classifying, analyzing and interpreting data and information. In this paper, ICT-based teaching under interdisciplinary theme will be discussed, based on the challenge and demand in the Fourth Industrial Revolution Era.

1 THE REQUIRED SKILLS FOR SOLVING PROBLEMS IN THE 4TH INDUSTRIAL REVOLUTION ERA

The distinct system and process of industry in The Industrial Revolution 4.0 bring a number of existing digital industrial technologies into an integrated system. This system covers the Internet of Things, Blockchain, Autonomous robots, Driverless vehicle, Autonomous vehicles, Artificial intelligence, Cloud computing, Big Data, 3D Printing, and Augmented Reality. All these available system, tools and media can be utilized for enhancing productivity in all aspects of our life, particularly in education. Labour, capital, and productivity are key factor in creating excellent growth of economy and education of a nation. However, in the Fourth Industrial Revolution, it is productivity which so far has triggered the growth of these two fields. The benefits of the Fourth Industrial Revolution technology adoption for manufacturing, economy and education, will be widespread, with smarter supply chains, smarter production and smarter products.

The Industrial Revolution 4.0 encourages us to live and work smarter, not harder. This reality can be observed from daily situation. For example, the merging of information and communication technology (ICT), together with the technology being applied, support almost all possibilities of automation that could speed up transportation, massive process improvements, fast enhancement and massive productivity. The innovation produces also alternative revenue sources, all of which have their foundations in information and services. Not only will manufacturing become more productive, it will also become more flexible, as smarter products could be resulted from smarter process of production, smarter transportation, and smarter supply chain. The innovation as the result of these advantages, however, could eventually lead to the disruption of existing business model, information availability and high-quality services, as well as system of education.

One of the main characteristics of the challenge in the Fourth Industrial Revolution era is that our world is now so complex, interconnected, and is dramatically changed from time to time. The appearance of phenomena of modernization, globalization and digi-

talization, have shaped this world without border. The demand from the world without border is skills required for excellent communication, direct or indirect, real or virtual, by empowering people in technology, whether technology in general, or information and communication technology. The flow of information, which is so tremendous in globalized world, requires skills for selecting and classifying data and information to draw precise and accurate conclusion. All information obtained should be analyzed and synthesized carefully to make it meaningful for the advancement of science and the preparation in facing complex and complicated daily problems.

The development of skills required for facing the problems in the Fourth Industrial Revolution Era need some materials which contain interdisciplinary themes including global awareness, financial literacy, civic literacy, and environment literacy. Toh & Kaur (2016) indicated that to fulfil these literacies, there are some skills needed: (1) Skills of Learning and Innovation, (2) Information and Media/Technology Skills, (3) The skills for Life and Career.

In facing this changing world, we require skills which should be developed. These skills consist of critical thinking, creative thinking, problem solving, communication, representation, and connection ability. On the other hand, nowadays, the development of quality of human resources through education, which can enhance the student achievement, is triggered by the development of technology. The advancement of science and technology has fostered the easiness of information access and shortened the required time to gain information. This easiness should minimize the problems in education, and particularly in mathematics education.

The existence of science and technology has provided students with broad access of information relevant to the need and demand; opportunities for doing exploration and self finding in mathematical concepts in the given computer program. This can trigger the empowerment of student skills optimally, so it can be expected that their critical thinking in mathematics can also be enhanced.

2 THINKING ABILITIES UNDER THE CURRICULUM 2013

Under the implemented national education system, Indonesia has high expectation of having high qualified, independent, creative, professional and productive community. These targets need serious efforts which should be developed by enhancing the quality of teaching-learning process and exploring the end-

less information, where thinking skills are the main focus.

Tracing and implementing the endless information require skills in accessing information sources, selecting and compiling the type of information, together with analyzing and drawing conclusion. This kind of abilities can be obtained through the development of critical, logical, systematic, analytical, creative, and productive thinking abilities.

The enhancement of critical and creative thinking abilities in formal education gained in high schools is developed by mathematics teaching, emphasized on system, structure, concepts, principle and the strong connections between one element and the others. These efforts require deductive thinking patterns in logic, as its application is required in daily activities. The concepts of mathematical logic can clearly explain and simplify a situation by abstraction and generalization.

Under the construction of Curriculum 2013 for high schools in Indonesia, there are a number of implications of different changes in mathematics education. The emphasis of this curriculum consists of (1) competency required for solving any problems related to mathematics; (2) competency of using mathematics as communication tools; and (3) competency of using mathematics as tools for reasoning in any situation, such as critical, logical, systematic, objective thinking and self-discipline in facing and solving problems. These abilities are extremely useful in attending higher education, constructing good communication in society, and preparing required skills for possible jobs.

The high expectation in the new curriculum cannot be handled by merely implementing conventional methods and approaches. To reach these mathematical competencies, some abilities in selecting materials on mathematics are required based on the structure of knowledge, the depth of materials, the characteristics of materials and their applications in real world. In addition, there should be a few methods and approaches that should be applied to accommodate all demands mentioned above. These new approaches which should be formulated, require optimization of student motivation; enhance student self-regulated learning; enhance the process of students' learning effectively; and counterbalance (keep up) the speed of science and technology development. One of the appropriate solutions considered as a good effort to realize these goals, is the application of information and communication technology as media in teaching mathematics, which give opportunities to students in learning mathematics independently through interactive programmed teaching materials.

3 COMPUTER AS DEVICES IN MULTIMEDIA-BASED TEACHING

Computer technology has been developed since the beginning of 1950s (Molenda et al., 1996) and since then computers have been contributing extraordinary advantages for community life. The greatest contribution ever in education area has been admitted long time ago, although the use of computers in schools was limited in word processing or worksheet only.

The use of computer software for teaching activities is not limited (Fey and Heid, 1984), and the potency of computer technology as media in mathematics teaching is so huge (Fletcher, 1983). There is so much real contribution delivered by computers for the advancement of education, particularly for mathematics teaching. Computer can be used for overcoming student individual differences; teaching concepts; carrying out calculation; and stimulating student learning (Glass, 1984). Students can manage their own learning, based on their level of skills. They can repeat many times until they really understand the concepts they learn. This is ideal for students who find difficulties in attending mathematics teaching, particularly for students who could be classified as slow learner. For students in fast learner category, they can be given enrichment to make them challenged and have special opportunity in exploring concepts deeply. Computers can guide students, starting from easy and simple concepts to complicated ones. By the help of its program, computer can give access to the students in analyzing and exploring some concepts of mathematics, so they gain better understanding in the concepts they learn.

Computer has unique advantages which do not belong to other media; for example, computer can give repetitive assistance; presenting material in much more interesting format and design, having good and interesting graphic animation and audio, and serving individual differences. As expressed by Wilson (Wilson, 1988), computers with good software design can present repetitive and dynamic presentation, a characteristic which can hardly found in any other media.

Some of computer advantages which are appropriate for mathematics teaching is its endless patience; can motivate students with designed reward; give opportunities to do experimentation without being anxious of possible damage; serve students indiscriminately; give students valued skill for their future, speed up their computation process which cannot be handled manually, or requires long time solution. The research by carried out by Kulik, Bangert-Drowns (Kulik et al., 2004) showed that compared to conventional teaching, interactive computer-based teaching

has some advantages. Among all advantages are as follows: the use of computer can strengthen students' ability in mathematics; students' speed in understanding the concepts will be even higher than their previous achievement, and the students' positive attitude towards mathematics will be much better.

As media for teaching, computer is not merely a tool which can carry out new situation, but also plays a positive role in developing students' talent and interest toward mathematics. This new situation, integrated in alternative teaching, can construct certain interest for students, so they will be motivated in attending the lesson, although the materials may be difficult to understand. In Indonesia, computer-assisted teaching is relatively new, so it can trigger students in learning mathematics, who might think that mathematics is a "dry" lesson, uninteresting, and difficult to understand.

4 INFORMATION AND COMMUNICATION BASED MATHEMATICS TEACHING

In interactive mathematics teaching, teaching materials are specially designed, so the interaction between students and computer go dynamically in stimulus-response type. Computers give students opportunity to enter input while computers give a response or vice versa. In the following process, the response can be a new stimulus so it triggers some other following responses which can strengthen student retention in the presented concepts. In stimulus-response type, program input can be constructed in various forms, so that it converges into the goals of teaching. When a student does a mistake, computer has to present explanation which guides them to the correct solution.

To construct computer software which can motivate students in such a way that they are interested in analyzing and exploring the concepts is certainly not simple. Software programmers have to design a program based on the students' mental development; they also have to understand pedagogical aspects, so the material presentation can be understood by the students properly. Kaput (Kaput, 1992) revealed that computer program-based teaching is not only based on assumptions as a guide, but it has also to be based on the expertise of the experts in implementing those assumptions in presenting the software, and relevant to the characteristics of the software and hardware they use.

The use of computers in schools can be classified in three models: the application of computer as tutor,

tool, and tutee. As tutor, computer assists students in understanding concepts, from the theory, theorem, until proofing, and exercises. As a tool, computer can be used by students for solving mathematical problems. Students can run special computer application programs relevant to the concepts they learn. By using this program students are enabled to analyze the characteristics of a notion (idea); for example, how to write a formula of a function when the formula is modified by manipulating its variable or constant. Through this pattern, students do exercises to analyze functions and find the relation between the graphics and their formula, so they can identify the characteristic of the function they observe.

As a tutee, computers act as an object which can implement all students' instruction, so computers follow all students' control. In this situation, computers do any given tasks.

5 INTERACTIVE MATHEMATICAL COURSEWARE IN THE IMPLEMENTATION OF E-LEARNING

After the invention of microcomputers with graphic interface, followed by the easiness of their operation and managed by consistent menu, the development of courseware-based education is a developed phenomenon which grows rapidly. This comprises Computer-Aided Instruction (CAI), Computer-Assisted Learning (CAL), Computer-based Training (CBT), Computer Conference, Electronic Mail (e-mail), Website, and Multimedia Computers.

Computer-based teaching materials can be considered as a set of techniques, software, and accompanying materials designed to be used in computer-based teaching, training, seminars/ workshops, or in any other education activities. Hatfield (?) indicates that computer-based instruction is basically an execution of computer programs for instructional purposes. In CAI, students are assisted step by step in understanding a topic. Students are given examples, exercises, questions, and tutorials. A computer program which is designed to make the students interested in the topic they learn can make the students reach the previous designated goals. Animation techniques, which are usually used in these programs, can motivate students extrinsically, as well as strengthen their interest.

Students can do distance discussion via computer conference, which can be held between remote schools. Students can pose their ideas and communi-

cate to each other without limitation of distance. Although these activities are usually conducted, computer conference, however, so far is considered as expensive option, and is not considered as an efficient mode of learning.

Web site can be used as media in mathematics teaching, although the teaching-learning process does not depend on the existence of website. Teachers can give tasks via website and provide the answers in the same media. This option of learning type can be integrated into e-mail use, so the teachers can communicate (in two-way traffic communication) to students, as well as between a student and the others, who can do discussion via this media. This type of learning is appropriate to be developed, particularly for distance learning, which enables students and teachers to have discussion without face-to-face meeting.

Teachers can explain concepts via multimedia computers, particularly concepts which contain motion, change, animation, or repetitive explanation, equipped by audio-video facility. Students get information via these media, whether in CD ROM, DVD ROM format, or even in common discs only. Teachers as a facilitator only need to operate these media whenever they need.

There are a number of computer-based teaching models, consisting of drill and practice, tutorial, game, simulation, discovery, and problem solving (Glass, 1984). In more details, there are several types of computer-based teaching interaction can be used, as follows: (1) Drill and Practice, (2) Tutorial, (3) Simulation, (4) Interactive discovery, (5) Games, (6) Presentation/Demonstration, (7) Test, (8) Communication, and (9) Information Sources.

6 DEVELOPING SOFTWARE FOR MATHEMATICS TEACHING

By identifying the characteristics of software mathematics teaching, together with its advantages, we can start developing interactive teaching materials by observing the has-to-be-followed steps. Some priorities which should be taken into account in dealing with software development for teaching are as follows: (a) Identifying the demands in learning outcomes, stipulated in the curriculum, (2) Evaluating all available software, (3) Enhancing the quality of the existing software, and (4) Developing new software.

In designing, developing, and implementing computer-based teaching materials, there are some steps that should be considered. Development phases which are required for designing high quality interactive teaching materials needs several phases. The first

phase is Analysis of Demand/Need. In this phase, it is required to analyze what topic needs presentation via computer-based teaching materials, how important it is, and what kind of difficulties usually found in conventional teaching. The other important aspect which should be put into account is the cost for designing the material by computer programs.

The topic designed in details should be done in the first phase to find out the content of teaching materials which will be designed, and what competency can be obtained from computer program to be adapted into instructional objectives, prerequisites, and animations to present the program more interesting and presented in well structure.

In the second phase, program design is started by setting the sequence or hierarchy of material presentation which is basically divided into input, process, and output sections. From each section, subsections of program which are interrelated can be designed.

The process of design is followed by program evaluation step, which tests whether the design is already feasible viewed from program requirement, such as system parameter and specification. In addition, it has to be ensured that viewed from pedagogical aspect, the presentation is already adequate based on student mental development, the sequence of concepts based on the prerequisite, accuracy in writing sentences, language aspects, including symbolic writing in formula and theorem. Program animation is not allowed to convert the concept and standard structure in a rigorous concept. This phase is often called as "test-belt stage".

The third phase: Development and Implementation Phase. In this phase, the computer program which consists of several modules/ subroutines are constructed based on the design of formulated flowchart. Each subroutine has to be analyzed by using various inputs, after which the subroutine is integrated into the main program or other subroutines. It may happen that a subroutine can be run when it does not involve any other subroutines, or it gets stuck when it is integrated with other subroutines or when repetition is implemented.

After the program have been integrated, in terms of variable (local variable and global variable) and the declaration of each subroutine, the whole program has to be run, and then analyses and evaluation step should be implemented, to see if there are some errors, by testing the output of the program and its results and display on the screen of computer.

To be successful, a program needs to be tested in a phase called as "piloting stage". In this phase, teaching material is tried out to a number of students, who have learned that material. A couple of problems arise

when piloting stage is implemented. However, these problems have to be identified and recorded, for the sake of the program refinement. Before a program is launched, improvement should be carried out based on the materials contained and the characteristics of the type of the program.

To obtain high quality teaching materials, we should select people who are involved in constructing materials for teaching in the form of computer programs. Their experience and knowledge of teaching will be really important as contribution to the high-quality design of teaching materials.

To assist education experts in designing teaching materials, system analysts are required for analyzing the system. However, some programmers are also required to help, in translating the basic ideas of teaching materials into structured computer programs.

To construct beautiful and interesting presentation, artists are required, provided that they are experts in audio-video programs. Their expertise in integrating the animation of audio and video, motion in graphic representation and animation, and any other aesthetic aspects will contribute to the excellent interactive teaching materials which can motivate student learning.

Apart from the abovementioned information, there should be also some editors and reviewers who are able to see the advantages and the weaknesses of the produced programs for refinement purposes. They consist of experts on pedagogy and experts in computer programming.

7 THE IMPLEMENTATION OF MATHEMATICS TEACHING ACTIVITIES

In conducting interactive teaching materials in schools, we should be aware of misleading in its implementation. It should be realized that computer is not a "panacea" which can cure all types of students' learning difficulties. Computer, however, is only a machine which is created by human being, but will not be able to replace the role of teachers. Computer, in its application, has to be integrated fully based on its potency and advantages in any stratum of education, as a tool as well as media in teaching.

As a matter of fact, the implementation of computer program in mathematics teaching cannot be always realized as the impact of difficulties in constructing computer programs, and computer program construction is time consuming. There are also some experts who think that teachers can be trapped in

designing and developing computer programs rather than analyzing and exploring concepts. Camp and Marchionini (Camp and Marchionini, 1984) even revealed that computer programming has potency of distracting the process of learning mathematics as it is time consuming and teachers focus their attention more on the program rather than the concepts of mathematics itself.

It is not easy for computer programmers to be skilful in designing instructional computer programs. This situation is easily understood as in designing and developing interactive teaching materials, a programmer not only has to understand a computer language but he/she also needs to understand instructional design, and of course, the concepts of mathematics. They have to direct their constructed programs for achieving the goals of teaching. Without all these things, computer-based instruction will be only the conversion of text from a book into a screen of computer, a failed effort.

8 FACING SOME CHALLENGES AND REQUIRED ACTIONS

To face the challenge of the new curriculum we need to prepare all strategies, approaches, and models of teaching, so that we can achieve the stipulated goals. Problem solving and reasoning skills require the help of computer media which can assist teachers in their teaching. Sufficient preparations are required to welcome the content and its resulted change, particularly the change paradigm from the teacher-centered paradigm to the student-centered paradigm.

To ensure that we are not left behind by many other countries, we need to take some efforts to be in the same level as the teachers in other countries. A number of Asian countries, including China, Thailand, and the Philippine have seriously implemented computer-based teaching by conducting some workshops and seminars on these matters, together with program evaluation. Singapore, Malaysia, and also Japan are developing computer programs devoting for the advancement of teachers and prospective teachers, particularly science and mathematics teachers (Calumpit, 2000). The question is: are we walking in the same place or will we move to follow other countries in shaping our beautiful and promising future?

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