IJECA
International Journal of Education & Curriculum Application
http://journal.ummat.ac.id/index.php/IJECA
ISSN 2614-3380| Vol. 5, No. 1, April 2022

Cyber-Physical System and Curriculum Heutagogy Implementation in Higher Education for Creating 4.0 Generation

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Keywords:

Heutagogy;
Cyber-Physical System;
higher education;
literature review.

ABSTRAK

Higher education management must change its management model because the student's current needs in the Industrial Revolution 4.0 era are very diverse and the demand from the industrial world is more specific. This situation required a new approach in learning that can meet the students learning needs, therefore, can generate higher education graduates that have the capability, not competencies. This article is compiled based on the results of thoughts supported by a literature review using content analysis based on the results obtained from 58 articles that were published between 1999 and 2020. The universities can implement heutagogy in the curriculum which is supported by the cyber-physical system in learning. This is causing the students to be able to choose scientific competence they want independently with learning across disciplines for occupying certain ability. The cyber system development in higher education is used to assist the online learning process and as an administrator in supporting learning activities. The cyber-physical system refers to the physical things and the campus atmosphere felt by the students.

Article History:
Received: 08-03-2022
Revised : 28-03-2022
Accepted: 28-03-2022
Online : 10-04-2022

Crossref
https://doi.org/10.31764/ijeca.v5i1.7971

A. INTRODUCTION

The development of the world today is greatly influenced by technological progress and innovation. This paradigm is known as the industrial revolution (Santos et al., 2017). The first Industrial Revolution gave birth to history when human and animal power was replaced by machines. One monumental mechanization was James Watt's emergence of the steam engine in the 18th century. This revolution has been recorded by history as a dramatic success in increasing the economy over the past two centuries. The second industrial revolution was marked by the emergence of power plants and combustion chambers. These discoveries triggered the emergence of telephones, cars, airplanes, which significantly changed the face of the world. Then, the third generation industrial revolution was marked by the emergence of digital technology and the internet that made "global villages" known as globalization (Lasi et al., 2014).

The fourth generation of this industrial revolution is called industrial revolution 4.0. Industrial Revolution 4.0 does not necessarily have a positive impact on humanity (Rauch et al., 2019). With the progress that is faster and more extensive than the previous generation. Industrial Revolution 4.0 has caused economic and social disruption (Baena et al., 2017). Industrial Revolution 4.0 is predicted will eliminate a few jobs in the future because they will be replaced by a robot and artificial intelligence. The jobs which will be replaced are teacher, journalist, bank teller, and interpreter. Although it is indeed predicted that there will be field jobs that will be lost, there will also be new jobs that emerge (Zhou et al., 2016). So it cannot be avoided if higher education institutions become the main focus in developing the "adaptation" mission of humanity in the Industrial Revolution 4.0 era (Tvenge & Martinsen, 2018).

Adaptation which can be done in educational orientation is to change the curricular end goal from competency-based achievement shifting to capability (Motyl et al., 2017). Why capability? The professional world experiences the dynamics of life that are no longer easy to predict, resulting in increasingly blurred definitions of social roles (Agonács & Matos, 2019). Even the term of capability which come from the UK in the 1980s has predicted that in the future the obstacle faced by an individual in their workplace will be more complicated (Davis & Hase, 1999). There have been many experiences of someone who quit one job and changed to another job as part of a worker's career. The labor market is getting higher so that the condition of higher education curriculum design based on predictions of social roles is currently increasingly inadequate (Eastwood & Sadler, 2013).

Competence is indeed an important element of capability (Chan et al., 2017). However, capable people are those who have meta competency and multi-skills abilities that can act effectively in overcoming new life problems (Zevin et al., 2019). The learning trend of the current generation is to hunt for capabilities. They learn whatever they want to engrave themselves as creators of professions and careers for themselves and when off-campus, learning resources are more up-to-date, high quality, and cater to their diverse tastes. Many students began to demand the life-based learning process and experience then became interested in the digital industry (Pereira & Romero, 2017). Nowadays students in their activities and interactions always intersect with globalization, automation, networking, and a changing world (Lund Dean & Fornaciari, 2014). Management of tertiary education is currently experiencing advancements in infrastructure, especially buildings and class facilities (Akram et al., 2016). But the culture of learning and teaching does not depart from decades-old traditions even a few centuries ago. The current system of higher education cannot provide a space for the convergence of diverse science and technology (Lafuente-Ruiz-de-Sabando et al., 2018). The learning system is not enough to provide the aisles of learning experience between scientific disciplines. The growth of study programs and scientific fields is hampered by interdisciplinary barriers. This becomes very common because solving a problem can not only be done by one discipline but requires study from various scientific angles (Benešová & Tupa, 2017).

Objectives reorientation of all higher education institutions is very urgent to do because the digital revolution has entered into all lines of life. The desired change is activity innovation in learning activities that essentially touches the level of the learning process and student learning experience (Wilson et al., 2017). How to build a learning climate that is directly experienced by students. How students can truly actualize themselves in learning accompanied by skills in the occupied field of science. For achieving all of this, it is necessary to review the types of skills achievement that will be addressed to higher education in the Industrial Revolution 4.0 era. Competence as a basis for achieving a higher education curriculum is considered inadequate. The complexity of life and employment demands multi-skills. Competence to meet the blueprint of the human profession derived from definitions of social roles or certain professions must have shifted towards the development of meta competence (Mohammad et al., 2019).

Higher education policies in response to Industrial Revolution 4.0 must be a moment to make fundamental changes in higher education management (Albert & Grzeda, 2015). The change in question is not just an instrumental change in educational input at educational practices such as changes from face-to-face to blended learning, or online distance learning, and building big data (Mourtzis et al., 2018a). Because furthermore Industrial Revolution 4.0 is not just the digitalization of education. The main vision of collaborative higher education management is the emergence of "smart factories", which will be linked to the industrial world (Anderson et al., 2017). With the concept of the Internet of Things, Internet services, and the Internet to people where there need to be in-depth analyzes to reduce the risk of educational institutions' failure in adapting to the needs of the industrial world.

One of the ways which can be done by higher education in creating graduates that have the high capability is to use a new approach in the curriculum (Dehghani et al., 2011). Industrial Revolution 4.0 generation requires an adjustment to the learning paradigm. Higher education is not pedagogical like the practice of education at the secondary and elementary levels. Higher education needs to be transformed into adult education (andragogy) which is the hallmark of education 2.0 and 3.0 (Rohayani et al., 2015). Shifting the orientation of tertiary education from achievement to competence requires updating the tertiary curriculum platform. The guidelines for developing a tertiary education curriculum that is currently in use by using a competency-based curriculum thinking model need to be updated (Joshua Earnest, Fr. Francis E. de Melo, 2011). The formulation of learning outcomes that are closed and tend to start one area of expertise needs to be reviewed. The learning outcomes objectives that are more open will give students the flexibility to develop their capabilities and expand to developing individual potential.

Judging from the current generation's condition, giving the role of students as their learning designers or called Heutagogy can be the main characteristic of higher education management following Industrial Revolution 4.0. Heutagogy, the study of self-determined learning, may be viewed as a natural progression from earlier educational methodologies, in particular from capability development - and may well provide the optimal approach to learning in the twenty-first century (S Hase & Kenyon, 2001). Hence heutagogy approach which can be interpreted as freedom in choosing the ability which is desirable by the students is currently considered more relevant than the andragogy approach that has been used for so long as a curriculum approach and learning in higher education.

Heutagogy implementation must be supported with high-speed Information and Communication Technology (ICT) (Stewart Hase, 2012). Information and Communication Technology is needed to assist in the complex learning process. Every student which is given the freedom to choose the competencies that they want will be troublesome for the university, lecturer, and relevant parties. Furthermore, every university has to have big data which is functions to record every students and lecturer's activities that is done from various places. Higher education curriculum that is prepared with a heutagogy approach must be strengthened by the Cyber-Physical System (CPS) owned by higher education institutions (Mourtzis et al.,

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2018b). If it is like this, what is the appropriate implementation process of the Cyber-Physical System so it can support the learning process using heutagogy?.

1. Heutagogy

Traditionally, education is always seen as a pedagogic relationship between teachers and students. Teachers always decide what the student must know and how science is also a skilled teacher (Bhoyrub et al., 2010). The research outcome in the last several years has been enough to give birth to an education revolution about how people learn and that outcome made teachers work further concerning the ways of teaching and the result from it. Consequently, with the community changing rapidly because of the information and technology development, it needed an educational approach in learning where students can determine what and how learning has to be done (Pantić & Wubbels, 2010). Heutagogy is a study regarding learning which the students determined independently, it also can be seen as a natural development of education methodology before especially from the skill development (Canter & Brumar, 2011).

Heutagogy comes from the Greek meaning for "self", firstly defined as self-determined learning (S Hase & Kenyon, 2001). Heutagogy applies a holistic approach to developing learning abilities by learning as an active and proactive process. Students act as "main agents" in their learning that occurs as a result of personal experience" (Stewart Hase, 2012). In the Heutagogy approach the educator facilitates the learning process by providing guidelines and learning resources, but in the course of the learning process is entirely left to students. The key concepts in heutagogy are double-loop learning and self-reflection. In double-loop learning, students consider problems and actions also the results produced. In addition to reflecting on the problem-solving process and how it affects students' beliefs and actions. Double-loop learning occurs when students "question and test one's values and assumptions as the core to enhance learning how to learn" (Stewart Hase & Kenyon, 2007).

Heutagogical approach can be seen as a development from pedagogy to andragogy, for heutagogy with the students' progress in adulthood and learning autonomy (Canning & Callan, 2010). The adult student needs less control from the teacher or instructor so their learning structure is more independent. While the student that less mature need more guidance from the teacher and instructor. In heutagogy, the students decide the learning program, design and develop the learning map from the curriculum for assessment (Stewart Hase, 2012).

When the students get older they will mature and increase their independence in learning. If we see from the role of the educators or instructor, when the students get older the role of instructor and structured material decreases On the other hand, for the younger students with the pedagogic approach, the role of the instructor and structured material is more dominant (Talati, 2014). This is the principle of heutagogy which is based on personality maturity in deciding the learning need because focuses on constructing the capability. Consequently, the more mature an individual the level of success in developing the capability is higher.

2. Cyber-Physical System (CPS)

Industrial Revolution 4.0 is marked by production system automation, with using a few technologies at the same time which formatted in one system called *Cyber-Physical through a process of programming algorithm.* A CPS is a mechanism through which physical objects and software are closely intertwined, enabling different components to interact with each other in a myriad of ways to exchange information (Zhong et al., 2017). A CPS involves a large number of transdisciplinary methodologies such as cybernetics theory, mechanical engineering and mechatronics, design and process science, manufacturing systems, and computer science (Uhlemann et al., 2017).

The cyber-physical system refers to a system that physically constructs, like a natural product and device that is made by a human, physically shaped and operated from time to time (Singh et al., 2019). A Cyber-physical system can operate when the system is connected with an internet network in real-time. The system becomes the basic development of various product capabilities, starting from product design, prepare prototype, making the diagnosis, monitoring, prediction, maintenance, information tracking, up to production network, a vehicle that used remote control, smart home, a various system which use by utilizing the internet network, sensor, and actuator in the planning and innovation making (Fitz et al., 2019). This system is very interesting because it became a foundation for capability development from a product.

Cyber-physical systems not only give birth to a new value to an old product but also can produce a new product which it never has been before (Liu et al., 2019). The existence of these products changes civilizations and our lives in many aspects. There is a mutual relationship of the internet network with the physical world, in this case, are sensors and actuators *(Alguliyev et al., 2018)*. In the internet network, various data can be identified, processed, and classified by sensor and actuator. Next, through a controller, it can be given an order for data retrieval, data process and even using these various data (Oks et al., 2019). Those data are from various sectors and purposes, such as for industrial, social institutions, government institutions, and education.

In higher education, Cyber-physical systems are divided into two, cyber and physical environment systems (National Academies of Sciences, Engineering, 2016). Cybersystems are relevant to the usage of internet networks in planning, implementation, and evaluation. Planning includes the activities which are usually done at the beginning of the academic calendar year such as perfecting learning plans, administration, and activities that relate to academics (Törngren et al., 2016). Implementation refers to administration fields, teaching, operational, and monitoring. Evaluation relates to reporting, improvement, and development (Jensen et al., 2013). All that process is done systematically connected with the internet and artificial intelligence device. Cyber-physical systems refer to physical things and the atmosphere felt by the universities. These activities can be seen from the facilities, learning activities, curriculum that is used, also learning strategies which all of it connected with the internet and artificial intelligence (Lawlor et al., 2013).

B. METHODS

This article is compiled based on the results of thoughts supported by a literature review using content analysis (Lafuente-Ruiz-de-Sabando et al., 2018). A literature review has been adopted as a research methodology. A literature review on a specific topic is worthwhile if there are a growing interest and accumulation of research on that topic (Twizeyimana & Andersson, 2019). A structured literature review is defined as a more narrative review because of its methodical approach, implying a detailed description of the steps taken to select, scan, and analyze the literature, aiming at reducing biases and increasing transparency (Dixit et al., 2019).

First of all, the authors collected papers through a search of the following electronic databases: IEEE, EBSCO Host, ProQuest, and Science Direct. The search was performed by combining the first four keywords with the last six keywords. Keywords used in the literature search were heutagogy, curriculum, higher education, Cyber-Physical System, and literature review. The search was limited to material available in the English language. Based on the search results, it obtained 58 77 articles were published between 1999 and 2020. Step two, paper selection, authors examine the abstract of each paper and found 35 articles that met the criteria (Copaci & Rusu, 2015). Criteria used for the papers that discuss the heutagogy in higher education and Cyber-Physical systems. Data results from the literature study are grouped and sorted according to the study. Next, the result of theory grouping and empirical studies from the journals is generalized by the writers for answering the problem formulation which appropriates the cyber-physical system implementation process so it can support the learning process that uses heutagogy.

C. RESULT AND DISCUSSION

Higher education must make changes and collaborate with the industrial world. Facing the disruptive technology era and innovation higher education institutions must make a paradigmatic leap (Lim et al., 2020). Because of that, it needed to prepare adequate facilities for cyber systems and physical systems from educational institutions starting elementary until university. It will produce higher education graduates which have the capability and apply to the need of the industrial world.

1. Cyber system

The main characteristic of 4.0 education is the utilization of digital technology in the learning and teaching process (cyber system), so science and technology transfer can be done continuously without always having face to face in the class (Jensen et al., 2013). In other words, the learning material can reach the students every time without being limited by space and time. As a supporter, big data management will be the backbone of higher education. Higher education that prints Generation 4.0 will rely on the integration of cyber systems and physical systems. This system requires a unique information technology architecture to create the interaction of three main subjects of education (lecturers, students, and curriculum) in the whole learning process. A transdisciplinary curriculum management system, a learning innovation platform for the development of meta-competencies and capabilities, and a learning management system must be built in a single unit of the Higher Education big data management system.

Especially the spatial design of the campus environment and its contents based on the Cyber-Physical System (CPS). A Cyber-Physical System is commonly referred to as a coupled system integrating computing, networking, and physical processes (Fitz et al., 2019). Cyber-Physical Systems is a dynamic field that requires an increased emphasis on multidisciplinary skills and significant enhancements in engineering curricula, renewed emphasis on systems sciences and engineering (Henshaw & Deka, 2018). Due to their rich infrastructure and set of basic services, future Cyber-Physical systems can accelerate the construction of innovative added-value services (Graessler & Poehler, 2019). An educational platform for Cyber-Physical System, as illustrated in Figure 1, should incorporate theory, Cyber-Physical System labs as well as more realistic industrial testbeds. In such a platform the Lab component plays an important role in dealing with the identified concepts and new technologies of the Cyber-Physical System in preparing trainees for the real world. It exposes training engineers to practical experimentation and interdisciplinary learning throughout labs and CPS design projects, with adequate hands-on experiments. The following is an image of the CPS platform design for education, as shown in Figure 1.

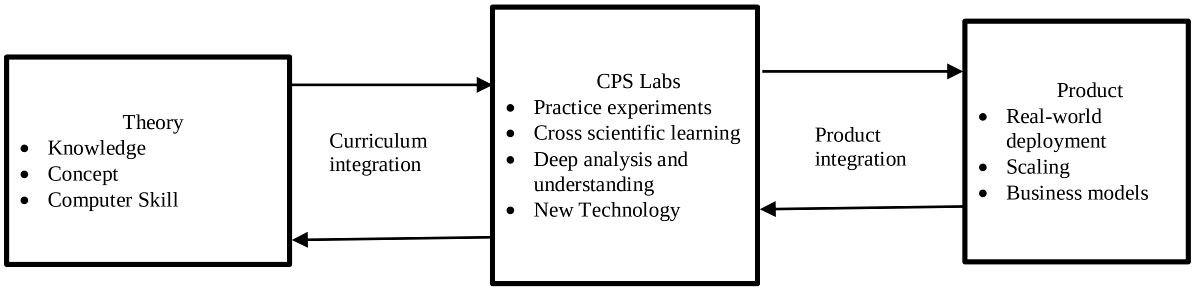

Figure 1. Educational Platform for CPS (Graessler & Poehler, 2019)

Figure 1 shows scientific theory consisting of knowledge, concepts, and computer skills integrated into a curriculum that provides a classroom learning experience involving technology, dynamic CPS, and dynamic analysis. The results of the collaboration of scientific theory with the learning process in the classroom produce products that are needed by the world of industrial and business models. Due to the disruptive nature of the Cyber-Physical System and the fast innovation cycles in information and communication technology, the half-life of state-of-the-art knowledge in several involved disciplines and technologies is short (Tanganelli et al., 2020). It is to ensure the necessary re-qualification, an academic-industrial alliance should engage established engineers in life-long learning through alumni programs or training courses offered by academic and industrial educational institutions and supported by industrial.

2. Physical system

In teaching, teachers need to strengthen character education and competence compatibility with the industrial world. One of the causes is the learning menu and portions as well as how to eat it are arranged and determined by educational institutions up to the class level (Wahab & Mustapha, 2015). Jobs and professions are defined by higher education as if the creators of jobs and professions are higher education institutions. The curriculum is designed as a human "blueprint" that is described exactly with the defined occupations and professions (Ozruso-Haggiag & Tabach, 2018). It is time to transform the heutagogy learning paradigm, which provides learning menu choices and opportunities for students to design their learning. This method is also relevant to the characteristics of the current generation that is not easy to accept certain roles and is strongly influenced by the internet (Alenezi, 2017). Some of them want to carve out a profession from their own identity.

There is no breach for students to choose the menu they like, mix it themselves, and eat it in their style and way. Higher education that produces Generation 4.0 requires dynamic and flexible transdisciplinary curriculum management (Bhoyrub et al., 2010). A "buffet" style curriculum management that provides interdisciplinary curricular menus needs to be developed to enable students to develop new studies in their scientific disciplines through a transdisciplinary learning process. Students are allowed to mix their own learning needs. Thus, naturally, there will be growth in new disciplines resulting from the transdisciplinary process.

The implication is that higher education institutions that print the 4.0 generation need a change in the architecture of the academic landscape that gives students the freedom to learn across disciplines (Shubina & Kulakli, 2019). Disruptive innovation is often born from the convergence and intersection of interdisciplinary science and technology (Lim et al., 2020). The convergence of science and technology takes place naturally in line with the increasingly broad democracy of knowledge and the openness of discipline as a result of the development of science.

The openness and ease of access to information through the internet in various disciplines facilitate the convergence of science and technology (Faqihi et al., 2018).

There will be no scientific discipline that is completely sterile from the influence of other disciplines. Every discipline will need a role or contribution from other disciplines. This academic nature requires a change in the overall academic landscape of higher education (Rauen et al., 2015). Hence, if it complies with the heutagogy approach, it needs a curriculum transformation from monodisciplinary to multidisciplinary and study program merger (Törngren et al., 2016). In the curriculum transformation aspect, it will allow someone to learn another aspect according to the student's needs or goals. For example, animal husbandry students want to know how to make a light steel cage, then they can take lectures in the architectural engineering program. Consequently, when the students graduate, they will have the capability to build chicken farms business and even be able to work in the light steel processing field.

The merger from some of the study programs becoming multidisciplinary has begun to happen at many universities in the world (Canning & Callan, 2010). This is happen because the universities respond to the information input or suggestions from their alumnus and graduates users that nowadays, a capability is extremely needed (Benešová & Tupa, 2017). It is intended that the graduates will have global knowledge and capability, so they can be accepted in industrial world or working fields with wide spectrum as the 4.0 industrial revolution demand. Now a lot of faculty only have one study programme as a form of respond of knowledge development and multidisciplinary capability. As an example; criminal law study programme, state administration law and international law are merged into one programme, law study programme; animal production study programme, cattle nutrition and socioeconomic animal husbandry can be merged into animal husbandry study programs, and others. The purpose is to produce graduates which have multidisciplinary competence in a particular discipline, so they will have more capability compared to only understanding monodisciplinary and it is very preferred by the industrial (Zezulka et al., 2016).

D. CONCLUSION AND SUGGESTIONS

Human resources which are needed by the industrial world nowadays is whose have capability not only competence. To produce 4.0 generations that are relevant to the need of the industrial world, a university can implement heutagogy in the curriculum that is supported by Cyber-Physical systems in learning. Heutagogy can be implemented only in higher education because it needed the students' maturity to develop the capability. The more students mature, the opportunity to develop their capability is bigger. The mature students will be more responsible and have goals and a desire to occupy a certain ability. This will cause the students to be able to choose independently the scientific competence which is desirable with learning across disciplines to occupy a certain ability. The development of the cyber system in higher education is used to support the online learning process and also administration in learning activities. The physical environment refers to the physical atmosphere felt by the university. The limitation in this research is needed to be empirically verified to the universities which implement heutagogy. This empirical study is to see the effectiveness and efficiency in a learning process that led to the success of the students after finishing the education process. The suggestions which can be given to the universities administrator is to direct the students to take subjects outside their main fields which they learn all this time. Next, start to build a Cyber-Physical System that supports heutagogy in learning because higher education in the 4.0

industrial revolution not only education digitalize but also Cyber-Physical System that supports the process of self-determining learning in occupying capability.

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