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Beliefs, Actual Practices, and Perceptions on the Implementation of 4C Skills-Integrated STEM Curriculum in Online Mathematics and Science Learning

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Abstract: This study tried to find out about beliefs, actual practices, and perceptions of educators and students of the Faculty of Mathematics and Natural Science, Universitas Negeri Surabaya, Indonesia on online education they experienced. The study focused on 4C skills being embedded in STEM curriculum implemented to some courses. The samples were 17 courses including corresponding educators and students who enrolled the courses. Data were collected by observing activities in LMS and synchronous web meeting and by giving questionnaires to the educators and the students. The results informed that educators and students were able to adjust and adapt to online learning with some shortcomings. Educators' belief that good online courses with 4C skills-integrated STEM curriculum is possible to conduct with some refinements. Students were able to follow courses which include 4C skills with the context of basic STEM knowledge. However, they did not prefer the use of LMS in their learning.

Keywords: 4C skills, STEM, online education, mathematics and science

Abstrak: *Penelitian ini bertujuan untuk memperoleh informasi tentang keyakinan (beliefs), praktik pembelajaran sesungguhnya dan persepsi tentang pembelajaran daring dari para dosen dan mahasiswa di FMIPA Unesa Indonesia. Penelitian difokuskan pada kecakapan 4C yang dimuat di dalam kurikulum STEM yang diimplementasikan pada beberapa mata kuliah. Sampel penelitian ini ada 17 di fakultas MIPA termasuk dosen pengampu dan mahasiswa yang terdaftar. Pengumpulan data dilakukan dengan mengamati kegiatan di LMS dan pembelajaran daring sinkronus (web meeting), serta pemberian angket kepada pada dosen dan mahasiswa. Hasil yang diperoleh menginformasikan bahwa para dosen dan mahasiswa mampu membiasakan dan menyesuaikan diri dalam pembelajaran daring dengan beberapa kelemahan dan kekurangan. Para dosen yakin bahwa pembelajaran daring yang mengintegrasikan kecakapan 4C pada kurikulum STEM sangat mungkin dilakukan dengan proses perbaikan. Mahasiswa mampu mengikuti perkuliahan yang memuat kecakapan 4C dalam konteks pengetahuan STEM dasar, tetapi mereka memilih untuk tidak menggunakan LMS dalam pembelajaran.*

Kata kunci: *kecakapan 4C, pembelajaran daring, matematika dan IPA*

▪ INTRODUCTION

The outbreak of the corona virus (COVID-19) that becomes pandemic throughout the world has practically changed the orientation and paradigm in various aspects of life, including in education. Due to WHO recommendation on social distancing (World Health Organization, 2020), teaching and learning practices cannot be done traditionally, face-to-face. So, the demand for online teaching and learning is more likely applicable in this situation, as proposed by Mnguni and Mokiwa (2020) and Pintarič and Kravanja (2020).

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Online education with its long history of development to encompass geographic and time differences between teachers and students has been implemented in higher education, particularly in open university institutions since the mid-20th century (Berg 2016). With the emergence and spread of computer-based communication, i.e. internet, the university delivers web-based courses which is cost effective and flexible. The implementation of this new mode in education brought the implication to education concept and organization, financial and other resource distribution and the role of teacher (Moore & Anderson 2003).

In practice, online education requires teachers to have technology literacy combined with appropriate (online) pedagogical and teaching skills as well as knowledge of learners' need. Kim and Bonk (Kim and Bonk 2006) conducted an online survey of college instructors' and administrators' beliefs on online education, particularly the linkage of (online) pedagogy, technology, and learner's need. The respondents were about 40,000 of college instructors' and administrators' who were members of institutions that have premier associations for online education. The results revealed that quite a number of respondents predicted the enormous increase on the use of learning management systems due to the emergence of advanced internet technology (e.g. bandwidth and wireless connection, video conferencing). Moreover, they also predicted that the availability of sophisticated technology for education would affect to the increase of learner demands for university to offer online master's or doctoral programs in the future. Nevertheless, the results also told that there would be another issue on the readiness of the online instructors to meet the challenges brought by the predicted increases in learner demand for online education.

As mentioned by Sammons (Sammons 2003), one of the challenges that are faced by online instructors is "migration" of teaching and learning conception from teacher-centered conception to student-centered conception. In this conception teachers/instructors are not only required technological skills but also (online) pedagogical skills that facilitate and moderate the learning according to learners' need ((Bonk, Wisher, and Lee 2004; Mishra and Koehler 2006)). Skills like facilitating interaction and fostering communication among students are highly needed (Easton 2003) in order to cope the problem of students' boredom whenever participating an online class (Kim and Bonk 2006) as well as to be successful in their learning.

With all of those challenges in conducting online education, especially in the pandemic era, teaching mathematics and sciences needs to transform the curriculum, instruction and assessment approaches that facilitate students' learning. (Erduran 2020). The curriculum as well as approaches implemented in online teaching for mathematics and sciences subject should be able to enhance students as future generations with knowledge and skills to deal with global concerns.

STEM education is a learning approach that integrates Science, Technology, Engineering, and Mathematics and applies it into one situated learning (Kelley and Knowles 2016). Through STEM education, in which interdisciplinary real-life applications of topics being taught are situated, future skills such as problem solving, creative and critical thinking, communication, collaboration (4C-skills), initiative, and digital literacy (P21 2007) of students can be developed.

The difference of STEM education with traditional mathematics and science education is the mixed learning environment that shows the students how scientific method is applied in real-life situations. Moreover, STEM education also teaches students to fulfill the need of well-trained workers especially in the technical areas of science, technology, engineering and mathematics and their applications for solutions of real-life problem (Trilling and Fadel 2009).

Due to increasing demands of high skill labor, in the last two decades many developed countries, namely European countries, the United States, and Australia have implemented STEM education. This trend was followed by emerging and emerged country throughout Asian countries, such as China, South Korea, Japan, Taiwan, and Japan as well as some other parts of the world, such as South Africa, Brazil, Argentina, Canada and New Zealand (Lee 2019; Marginson et al. 2013). The implementation of STEM education is from elementary school level to higher education level (Keengwe and Kidd 2010; Smith 2019). These show the importance of educational system that accommodate the development of students' knowledge and skills that fit to industries need. In the pandemic era, the implementation of STEM education both in schools and universities will be well fitted if it is combined with the availability and students and teachers' readiness of e-learning (Latchem and Jung 2009), including the use of internet and learning management systems (LMS).

With all of the backgrounds mentioned above, it is necessary to study about the implementation of STEM education that integrates problem solving and 4C skills based on the real experiences of the educators and students during the pandemic. The result of this study might be considered a rough portrait of the implementation of online education and can be used for the purpose of evaluation for better and effective online education in the future.

▪ METHOD

This is a descriptive exploratory research with qualitative and quantitative approaches. The research was done at the Faculty of Mathematics and Natural Sciences of a university in Indonesia. The faculty runs not only pure mathematics and science study programs, but also mathematics and science education study programs. The faculty has 156 faculty members and 2473 students of nine study programs. The data collected were from both two groups of study program. The samples of this study consisted of two cohorts from both groups of study program. The data were collected from the faculty students and faculty members by using questionnaires for their beliefs and expectations on online teaching/learning and some virtual classroom observations for their actual practices in the classroom. Using cluster random technique, the sample of virtual classrooms to be observed was chosen from all virtual classrooms that were offered in the semester. Meanwhile, the sample students and faculty members were chosen by using two-staged cluster random technique (Fraenkel and Wallen 2009).

Based on sampling techniques being used, there are 16 virtual classrooms, 33 staff members, and 419 students were chosen as the samples of this study. Table 1 presents the overall sample composition of virtual classrooms being observed, while Table 2 and 3 present the overall sample composition of staff members and students who were involved in classrooms mentioned in Table 1.

Table 1. The composition virtual classrooms

Study Programs	Name of Courses
Mathematics/Mathematics Education	Elementary Linear Algebra Elementary Number Theory Research Operation School Mathematics
Science/Science Education	Plants Anatomy & Physiology Genetics Endocrinology Immunology Quantum Physics In-organic Chemistry Computation Chemistry Science, Technology, Environment, and Society ICT-based learning in Science Mathematics Physics Foundation of Education Game Media in Chemistry Learning

Table 2. Staff member composition

	Math	Science
Female	6	13
Male	5	9

Table 3. Student composition

Pure Math	Math Education	Pure Science	Science Education
66	78	109	166

Questionnaires for educators and classroom observations were adapted from Online Learning Strategies, University of Toronto (Harrison and Heikoop 2016) that is focused on educators' beliefs and actual practices on online learning integrating 4C skills based on STEM curriculum. The instruments consist of four sections containing 18 items as shown in Table 4.

Table 4. Sections and number of Items of questionnaires for educators and observation protocol

Section	number of Items
General Overview and Introduction	4 items
Assessment of Student Learning	3 items
Instructional Design	5 items
Online Organization and Design	6 items

Notes: Scales for educators' belief: Strongly Agree, Agree, Not Agree, Strongly Not Agree, Scales for educators' actual practices: Very Good, Good, Fairly Adequate, Poor.

Questionnaires for students was adapted from *Readiness of VET clients for flexible delivery including on-line learning Brisbane: Australian National Training Authority* (Warner, Christie, and Choy 1998) that is focused on students' readiness toward flexible delivery including online learning that integrates 4C skills based on STEM curriculum. The questionnaires consist of three sections containing 22 items as shown in Table 5.

Table 5. Sections and number of items of questionnaires for students' readiness

Section	Number of Items
Students' preferences for the form of delivery	6 items
Students' confidence in using electronic communication in learning	8 items
Ability to engage in autonomous learning	8 items

Notes: Scales for students' readiness: *Strongly Agree, Agree, Not Agree, Strongly Disagree*

The analysis was based on the percentage of upper scales (Agree and Strongly Agree in educators' beliefs and students' readiness and Very Good and Good in educators' actual practices) with respect to the total data of each item were calculated. The analysis was also based on the means of the percentage of item in each section. The percentages and means were compared or contrasted to draw partial (each item/section) or overall conclusions.

▪ RESULT AND DISSCUSSION

Data being obtained were analyzed by comparing and contrasting the means of the percentages of upper scales of the instruments. These do not aim to generalize the differences, but rather to explain the patterns in the data for further investigation and research. The analyses were based on each aspect both in the questionnaires and the observation protocol.

First, the analysis aimed to compare educators' beliefs with their actual practices on online teaching integrating 4C skills based on STEM curriculum. Table 6 indicates the means of percentages of upper scales of questionnaires of educators' beliefs compared to the classroom observation of the corresponding educators.

Table 6. Comparison of educators' beliefs and actual practices on online teaching

	Course Review and Introduction	Assessment of Students' Learning	Instructional Design	Online Organization and Design
Educators' beliefs	0.93	0.88	0.96	0.95
Educators' practices	0.84	0.88	0.95	0.93

From Table 6 it can be noticed that overall means of all sections of educators' beliefs and actual practices are higher than 0.8. These mean that most educators believe that they should integrate 4C skills based on STEM curriculum in all aspects of four sections of their online courses. Similarly, most educators also had integrated

4C skills based on STEM curriculum in all aspects of four sections when teaching their online courses.

In Section *Course Review and Introduction*, more educators (93%) believe 4C skills and basic STEM knowledge need to be integrated in all aspects of the section compared to those who integrated the skills and knowledge in the corresponding section in their actual practices (84%). About 7% of them believe that they do not need to describe in the introduction that basic STEM knowledge and exhibiting 4C skills are required in all aspects of the section. Meanwhile, about 15% of educators do not agree that 4C skills and STEM knowledge need to be mastered and exhibited in all aspects of the section. Those who believe that 4C skills and basic STEM knowledge no need to be mastered and exhibited are educators who teach courses in pure mathematics which, according to them, hardly use the skills and the knowledge.

In Section *Assessment of Students' Learning*, the number of educators who believe and practice that 4C skills and STEM knowledge need to be assess in their online courses are the same (0.88). The rest of them (about 12%) believe that they have difficulty to put 4C skills and basic STEM knowledge as parts of the assessment of students' learning, because they hardly involve those aspects in practice. Again, educators who have difficulty to put 4C skills and basic STEM knowledge as parts of the assessment are those who teach courses in pure mathematics.

In Section *Instructional Design* and Section *Online Organization and Design*, most educators (93% and above) believe that 4C skills based on STEM knowledge are necessary in both the design instructional and online organization and design. There are two educators (about 5%) who do not provide reflection and feedback and guidelines for tools usage in their actual classroom practice, although they believe that those aspects are necessary to provide. On the other hand, in practice most educators also had integrated 4C skills based on STEM curriculum in all aspects of those sections of their online courses.

Second, the analysis also aimed to describe students' readiness in attending online courses that integrate 4C skills based on STEM curriculum. Table 7 indicates means of each aspect of the three sections of the questionnaires, namely Preferences for the form of delivery, Confidence in using electronic communication in learning, and Ability to engage in autonomous learning.

In Section *Preferences for the Form of Delivery* most students need basic STEM knowledge when learning the concept. Meanwhile, they realize that to able to follow STEM curriculum, they need to practice 4C skills in order to understand the concept being taught. In addition, when attending the course students feel that educator's feedback on the tasks being assigned and the use of media by the educator help them to comprehend the concept. On the other hand, a number of students are not used to use LMS as a learning resource. They find it difficult when learning the material asynchronously through LMS, even though they can access it as often as they like.

In Section *Confidence in Using Electronic Communication in Learning* almost all students do not have any difficulty in utilizing technology used in the courses. They are already familiar with the format of online courses (in LMS), including applications and tools for doing assignments or exploring, up- and downloading materials from/through the internet.

In Section *Ability to Engage in Autonomous Learning* most students are able to practice 4C skills basic STEM knowledge during the courses. They feel that they are facilitated enough to communicate with friends and educator to discuss about the materials. They also feel that they are given enough opportunity to work in group and try to work individual and independently. However, quite a number of student object to master basic STEM knowledge and are reluctant to exhibit 4C skills during the course. About half of them are not motivated and still have difficulty in online learning.

▪ CONCLUSION

From the previous section, there are some results which are interesting to be pointed out. Despites a quick transition due to the pandemic, both educators and students are able to adjust and adapt the situation with some shortcomings. Online learning is the most reasonable alternative to conduct teaching and learning process. From educators' view point, the high scores on their beliefs reflect the awareness staff members of the faculty for the implementation of good online courses integrating 4C skills based on STEM curriculum, although in practice a number of educators (about 12-15%) have not really implemented STEM curriculum, especially in Sections General Overview and Introduction and Assessment of Students' Learning.

Students' view point tells that although most of students (90% or more) confident in learning using electronic communication and they prefer basic STEM knowledge and 4 Skills to be included in their learning outcomes, in practice quite a number of students (about 15%) do not like LMS as a medium of study and it does not help them enough to study. This is very much as a result of their lack of ability to engage autonomous learning. This is due to their un-readiness of e-learning (Latchem & Jung 2009) and it needs the commitments of government to facilitate them.

The implementation of online learning that integrates 4C skills based on STEM curriculum among staff members of the faculty can be improved based on abovementioned results. Since about 50% students feel that online learning does not motivate them and does not help them enough to comprehend the course materials, it is necessary to design the syllabus that considers a better (online) pedagogy that helps students to be more self-regulated in their learning process (Horn, Staker, and Christensen 2014). On the other hand, implementing STEM curriculum that contains 4C skills is an important issue to be addressed, especially for mathematics and science faculty, in order to equip the graduates of the faculty with the 21st century skills ((Marginson et al. 2013; P21 2007)).

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