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Developing Performance Assessment Instruments to Measure 4C Skills in Online Discussion Activities of Science Learning

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article info	abstract
	The 21st century learning utilizes information technology for various activities, including online discussion forums, to increase students' learning activities and learning interaction. The 4C's performance assessment instrument in the online discussion forum is not yet available, thus, a 4C's assessment, including communication, collaboration, critical thinking, and innovative creative thinking skills, is necessary to assess students' performance in the process of online discussion activities. This research aims to develop 4C's performance assessment instruments in the online discussion process using the ADDIE model. Meanwhile, instrument development included analysis, design, development, implementation, and evaluation. The instruments were in the form of observation sheets and assessment rubrics. This study tested 4C's observation instruments in 104 students in online discussion activities during four online discussion activities. Data analysis included construct validity and reliability of each instrument indicator. The data analysis reveals that the 4C's performance instruments are useable to measure students' 4C's skills in online discussion forums. 2020 Scientiae Educatia: Jurnal Pendidikan Sains

1. Introduction

Online learning has become a trend and is the best learning solution during the COVID-19 pandemic. Several limited preliminary studies denote that many educational practitioners use social media as a means of discussion activities. This is related to the essence of learning as an interactive process between educators and learners. The advantage of discussion activities is the possibility of knowledge transfer among participants. Moreover, online discussion forums discuss various alternative references to solve problems in science learning. The 21st century learning is characterized by ICT-based learning utilizing various internet facilities as a learning resource (Kivunja, 2015). This underlies the importance of applying the internet as a learning resource in online learning discussions to solve science learning content problems. The 21st century skills describe strategies used to teach the skills to students, and educational institutions must facilitate the improvement of students' skills through the learning process for their 21st century success. Learning by utilizing mobile devices and technology improves internet access and optimizes limitless learning. The 21st century skills refer to the framework of 4C skills

(4C's) designed by the National Education Association (2012), these skills include communication, collaboration, critical thinking, and creative thinking ability.

Many online discussion activities are conducted using various paid and unpaid platforms. Online discussions offer better interaction and information and knowledge sharing than offline discussions. Some educators find that assessing online discussion activities integrated with the 21st century skills, which is 4C's, is difficult. Evaluation tools that measure 4C's (communication, collaboration, critical thinking, and innovative-creative thinking skills) and applicable for any online learning discussions are not yet available. An assessment could be performed by observing students' active participation in classroom learning (Armstrong, 1978; Armstrong & Boud, 1983; Cann et al., 2006). Discussion activities are conducted in online classes, then data are collected by observing the participants' interactive and interpersonal responses to online discussion activities (Beuchot & Bullen, 2005). Student interaction by giving mutual responses in discussion activities is student performance (Balla & Boyle, 1994; Lee, 2008; Brent et al., 2009). Online discussion activities require an instrument to measure the 4C's of student interaction through their responses in the online discussion activities. Therefore, it is necessary to develop a valid and reliable evaluation tool that measures 4C's in online discussion activities of any subject.

2. Method

This study aims to develop a performance assessment of students' 4C's in online discussion activities. This study employed the ADDIE model approach consisting of five phases: analysis, design, development, implementation, and evaluation to develop a 4C's assessment (Kurt, 2019). The stages of developing 4C's instruments with the ADDIE model are presented in Table 1.

Table 1. Research steps with the ADDIE model

No	Phase	Description	Activities
1	Analysis	Conducting a need analysis to evaluate online discussion activities, assessment techniques, and types of platform used	Selecting the right framework to measure 4C's in online discussion of science learning contents on any platform
2	Design	Conducting a literature study of online discussion activities and 4C's	Designing evaluation tools to measure 4C's based on the selected framework
3	Development	Designing an evaluation tool to measure 4C's	Developing 4C's assessment instruments: an observation sheet and an assessment rubric with scoring types

No	Phase	Description	Activities
4	Implementation	Developing an online discussion assessment to measure 4C's	Testing the instrument in 104 students divided into three online discussion groups
5	Evaluation	Conducting a 4C's assessment trial	Analyzing students' responses in online discussion activities, constructing validity tests with the product-moment test, and conducting reliability tests with the Cronbach alpha test

A literature study was conducted by reviewing and analyzing several articles, and this study selected a framework to compile the instrument from each 4C's domain, as presented in Table 2.

Table 2. 4C's Instruments

No	Instruments	Framework
1	Communication skills	Donovan et al. (2014)
2	Collaborations	Binkley et al. (2012)
3	Critical thinking	Facione et al. (1990)
4	Innovative-creative thinking	Donovan et al. (2014)

The next stage was designing 4C's assessment instruments by determining the framework and compiling each framework into several indicators. An assessment rubric was created and derived from the indicators of each 4C's domain. These Indicators are presented in Table 3 until Table 6.

Table 3. Framework and indicators of communication skills

No Item	Communication skills	
	Framework	Indicators
1	Written communication skills	Written communication skills on online discussion forums
2	Positive and productive interaction and communication with others	Positive communication with others
3		The frequency of communication and interactions with others
4		Appreciation for different opinions
5	Ability to demonstrate working in diverse teams effectively and responsibly	Students' ability to demonstrate working in diverse teams effectively
6		Students' ability to demonstrate working responsibly

Table 4. Framework and indicators of collaboration skills

No Item	Collaboration	
	Framework	Indicators
1	Individuals' role in groups	Knowing when to listen and when to speak
2		Knowing and recognizing the individual's roles in a successful team
3		Knowing how to plan, organize, and fulfill group goals
4		Remonitoring and replanning when obstacles from unexpected developments occur
5	Respecting group members	Speaking clearly, having full awareness of speech, and agreeing with the group's goals

No Item	Collaboration	
	Framework	**Indicators**
6		Listening to others carefully, patiently, and honestly
7		Treating teammates respectfully and professionally
8		Respecting the teammates' differences in generating new ideas
9	Prioritizing group's goals	Improving innovation and quality of work as a team
10		Prioritizing, planning, and managing the division of tasks to achieve the desired group results
11		Using interpersonal skills to influence and direct team members towards common goals
12	Contributing to the achievement of the group's goals	Using problem-solving skills to influence and direct team members toward common goals
13		Responding with an open mind to ideas and values
14		Acting responsibly to the larger community's interests

Table 5. Framework and indicators of critical thinking

No Item	Critical thinking	
	Framework	**Indicators**
1	Interpretation	Understanding the learning themes and objectives
2		Expressing the intent of various situations, data, judgments, rules, procedures, or criteria
3	Analysis	Linking information and concepts at issue
4		Clarifying conclusions based on the relationship between the questions and the information in the problems
5	Evaluation	Assessing the credibility of a statement or other representations of someone's opinion
6		Assessing a conclusion based on the relationship between information as well as concepts and the 'a problem's questions
7	Inference	Identifying the necessary elements to draw rational conclusions by considering relevant information to an existing problem
8		Identifying the necessary elements to draw rational conclusions and considering relevant information and its consequences based on existing data
9	Explanation	Providing reasons
10		Expressing evidence-based reasons, concepts, methodology, and information-based logical criteria

Table 6. Framework and indicators of innovative-creative thinking

No Item	Innovative-creative thinking
	Indicators
1	Using a variety of idea generation techniques
2	Creating new and useful ideas
3	Formulating ideas
4	Refining ideas
5	Analyzing ideas
6	Evaluating ideas

Table 3 until Table 6 shows the 4C's domains and their indicators based on the referenced framework in Table 2. Each domain's indicators were then derived in an assessment rubric representing in a scoring system. The 4C's observation instruments developed were then tested in 104 students during four online discussion activities.

The 4C's instrument trial was conducted in an online discussion about the concept of genetic engineering in the genetics course. The 4C's instruments were tested in 104 students; the research participants were divided into three large groups. Each large group was divided into three small discussion groups. During the online discussion, the members' opinions were monitored and observed to discover their 4C's. This research developed discussion themes applied in online discussions using the Gen-21cs application platform (Maryuningsih et al., 2019), as presented in Table 7.

Table 7. Online discussion themes using the Gen-21cs application

Sub-concept	Sub-concept	Sub-concept	Number of discussions (week)
The use of DNA technology to study gene expressions and functions by biologists	Describing some examples of biologists' research using DNA technology to study gene expressions and functions	The modification of CRISPR technology as genome editing on the genome	1
The benefits of cloned organisms and stem cells to basic research and other applications	Describing some examples of cloned organisms and stem cells useful for basic research and other applications	Cloning in plants and animals	1
The effects of the practical application of DNA-based biotechnology on human's lives in many ways	Describing some examples of practical applications of DNA-based biotechnology affecting human's lives in many ways	Practical applications of DNA-based biotechnology in health, pharmacy, forensics, environment, and genetically modified organisms (GMO)	2

The 4C's data were collected by observing the participants' responses in online discussion activities. This result agrees with Beuchot and Bullen (2005), who asserted that there were interactions and interpersonal skills in online discussion forum activities; thus, assessing online discussion activities was conducted through responses (Cann, et al., 2006; Balaji & Chakrabarti, 2010; Cross & Palese, 2015) to discover the discussion participants' high level of thinking (McLoughlin & Mynard, 2009). Students' responses in online discussion activities were coded based on the rubric of each 4C's domain. The data were in the form of 4C's domain scores and consisted of communication, group collaboration, critical thinking, and innovative-creative thinking skills. The discussion participants' 4C's were observed by reading their responses, in class discussions and group discussions. The responses were then analyzed based on the 4C's

domain instruments and their rubric. Three observers conducted the observations, and their observation results were used as mean scores of each 4C's domain. The participants' 4C's were observed in each online discussion activity. Therefore, the data of the 4C's domain scores were the average scores of all online discussion activities. The construct validity of 4C's domain data analysis was gained by using the product-moment test, and its reliability was gained by using the Cronbach alpha test.

3. Result and Discussion

The test results of the 4C's assessment instruments are in scores for each 4C's domain indicator. The mean score of each 4C's domain from the discussion participants' responses was analyzed by using r count of the product moment to gain construct validity and by consulting the Cronbach values to gain reliability. The results of the construct validity test on the instruments' indicator items are presented in Table 8.

Table 8. The validity test results of 4C's

No Item	Communication skills		Collaboration		Critical thinking		Innovative-creative thinking	
	r count	Criteria	r count	Criteria	r count	Criteria	r count	Criteria
1	0.281	Valid	0..738**	Valid	0.476*	Valid	0.516*	Valid
2	0.570**	Valid	0.478*	Valid	0.476*	Valid	0.856**	Valid
3	0.520*	Valid	0613**	Valid	0.4456	Valid	0.404*	Valid
4	0.679**	Valid	0.333*	Valid	0.937**	Valid	0.462*	Valid
5	0.483*	Valid	0.772**	Valid	0.476*	Valid	0.460*	Valid
6	0.790**	Valid	0.731**	Valid	0.456*	Valid	1.000**	Valid
7			0.556*	Valid	0.4456*	Valid		
8			0.400*	Valid	0.937**	Valid		
9			0.569**	Valid	0.495*	Valid		
10			0.617**	Valid	0.513*	Valid		
11			0.772**	Valid				
12			0.499*	Valid				
13			0.591**	Valid				
14			0.408*	Valid				

Information: n :104, r table: 0.195

Table 8 shows that all items of the 4C's domain indicators are valid because the r count is greater than the r table (0.195) with 104 samples. The construct validity test results in Table 5 show that the 4C's observation instruments are valid, and thus, the observation instruments are applicable to measure 4C's in online discussion activities. The reliability test results of the observation instrument for each 4C's domain are shown in Table 9.

Table 9. The reliability test results of 4C's

No Item	Communication skill		Collaboration		Critical thinking		Innovative creative thinking	
	Cronbach's Alpha	criteria	Cronbach's Alpha	criteria	Cronbach's Alpha	criteria	Cronbach's Alpha	criteria
1	0,737	Reliable	0,7239	Reliable	0,7122	Reliable	0,813	very reliable
2	0,693	Reliable	0,7375	Reliable	0,7122	Reliable	0,792	Reliable
3	0,702	Reliable	0,7288	Reliable	0,7197	Reliable	0,841	very reliable
4	0,676	Reliable	0,7426	Reliable	0,5848	Quite reliable	0,841	very reliable
5	0,710	Reliable	0,7173	Reliable	0,7111	Reliable	0,804	very reliable
6	0,638	Reliable	0,7295	Reliable	0,7117	Reliable	0,789	Reliable
7			0,7316	Reliabel	0,7197	Reliabel		
8			0,7400	Reliabel	0,5852	Quite reliable		
9			0,7294	Reliabel	0,7106	Reliable		
10			0,7321	Reliabel	0,7114	Reliable		
11			0,7173	Reliabel				
12			0,7364	Reliabel				
13			0,7301	Reliabel				
14			0,7399	Reliabel				

Table 9 shows that the observation instruments for each 4C's domain are reliable because the Cronbach alpha values of nearly all indicator items are above 0.5, and it means that the instruments' criteria are above the fairly reliable ranges: reliable and very reliable. This proves that the 4C's observation instruments consistently measure 4C's in online discussion activities. The analysis results of the construct validity and reliability of the 4C's instruments presented in Table 5 and Table 6 reveal that the observation instruments had met the requirements to measure 4C's. The construct validity of the 4C's domains relates to what extent the observation instruments can measure 4C's. Therefore, the validity of 4C's domain instruments was fulfilled. This implies that the students' 4C's information from the measurement can be interpreted as the results obtained. This statement agrees with Ancok's (2002) statement asserting that if the measuring tool has construct validity, all the measurement items will measure the concept.

The 4C's instruments observed in online discussion activities will be a non-test instrument with valid construct validity if the instruments are applicable to measure 4C's. The Cronbach alpha values of each 4C's domain indicator item obtained reliable criteria. This result indicates that the instruments used to measure 4's are consistent, and result scores are consistent. The observation instruments measured 4C's repeatedly for 4 discussion activities, and the results were relatively stable or consistent. This finding proves that the 4C's instruments are reliable. The reliability level is indicated by numbers called the reliability coefficient. The higher the reliability coefficient of an instrument is, the smaller the possible errors will occur. The

measurement error is relatively small when the Cronbach alpha value obtained is high. As a result, the 4C's instruments developed are applicable to measure 4C's in online discussion activities. The analysis of the product moment and Cronbach tests were conducted to gain construct validity and reliability, and the results reveal that the 4C's assessment instruments are valid and reliable. This proves that the 4C's observation instruments developed are valid and reliable; thus, they are applicable to measure (Biasutti, 2017; Wolf et al., 2015; Ercikan & Oliveri, 2016; Todd & Romine, 2017) students' 4C's in online discussion activities.

Black and Wiliam (2018) explained that in assessing students' performance, the pedagogical aspects of classroom assessment were compulsorily considered. This research developed an assessment to measures 4C's in online discussion activities by considering pedagogical aspects and assessing all online classroom activities. Integrating all 4C's domains in a learning process agrees with studies which state that students' classroom learning activities can assess their performance in general (Baird et al., 2017; Black & Wiliam, 2018). An interaction between educators and learners occurs in the learning process. It is a process of learners' performance and assessable. The 4C's consist of communication, collaboration, critical thinking, and innovative creative thinking skills measured by observing online discussion activities. This statement is consistent with the statement who asserted that the assessment was conducted by observing participants' active participation in online classes (Armstrong, 1978; Armstrong & Boud, 1983; Cann et al., 2006). 4C's data were collected by observing the participants interactions and interpersonal skills in their responses during online discussion activities (Beuchot & Bullen, 2005). The interaction of participants' responses in the online discussion process indicates that they are performing (Balla & Boyle, 1994; Lee, 2008; Brent, et al., 2009, Maryuningsih et al., 2019) their communication, collaboration, critical thinking results, and innovative-creative thinking reflections.

The 4C's assessment instruments developed are effective because it can measure four skills in one activity. Students' performance derived from their responses in discussion activities agrees with the standards of learning objectives in higher education (Rovai, 2007; Christopher et al., 2004). These objectives measure the profile of students' 21st century abilities using comprehensive assessment techniques in online classrooms (Landis et al., 2007; Akyol & Garrison, 2011; Cross & Palese, 2015; Dubuclet et al., 2015; Wolf et al., 2015; Black & Wiliam, 2018). Students' responses to online discussion activities are a combination of collaborative work between their written responses and their online discussion activities (Matheson et al.,

2012; Liu et al., 2017; Biasutti, 2017). Students' responses in online discussion activities are in the form of texts (McLoughlin & Mynard, 2009; Spatariu et al., 2004; Thomas & Graham, 2018; Wanas et al., 2008) and transcripts of discussion activities. These forms were then coded and analyzed. The coded text was then analyzed based on the 4C's domains. The data of each 4C's domain is in the form of scores as they are a non-test instrument (Wanas et al., 2008; Wilson et al., 2016). Moreover, the levels of consistency and consistency in measurement were analyzed. The constant and consistent validity and reliability prove that the 4C's assessment instruments developed are directly applicable and adoptable in online discussion activities of science learning.

An important element of online communication in discussion activities, as evidence of feedback, interaction, and in online class processes, is to assess students' conversational transcripts (Charalambos et al., 2004; Copping, 2016). Online classrooms utilize structured-alternative assessment methods to provide broad freedoms for learners to make decision in the learning process (Huxham et al., 2012; Fattah, 2015; Awada, 2016). Online discussion technology provides the ability for each learner to respond to questions (O'Reilly & Newton, 2002), participate equally, and potentially support learners' independent knowledge construction in meaningful discourse (Conole & Fill, 2005). The learning process of online discussion forums increases the learning process activities through the responses given in discussion activities. Discussion participants' comments are linked to reference sources, trigger, and synthesize learners' new thoughts; and thus, they share information, experiences, and supports with other discussion participants.

4. Conclusion

Online discussion activities are a learning process, in which there is interaction between learners, sharing information and knowledge. The active participation of discussion participants is a student's learning performance and psychomotor aspects. The 4C skills assessment in online discussion activities developed is valid and reliable, so it can be used to measure 4C skills in students through online discussion activities. This 4C skill instrument can be used for online discussion activities on learning any content.

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