
FRAMEWORK AND PROTOTYPE DEVELOPMENT OF MATHSCI INSTRUMENTS FOR MEASURING 21STCENTURY SKILLS IN ISLAMIC CONTEXT

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Received: 18th April 2021; Revised: 17th May 2021; Accepted: 28th June 2021

Abstract

The development of competency assessments that measure 21st century competencies is critical for improving the quality of education. The purpose of this research is to describe a framework and prototype for assessing Math and Science or Math-Sci competency skills in the twenty-first century. The method of development research employed in this study is based on the Akker framework, which entails preliminary research, prototyping, design, and development in a paper and pencil test format. The equipment of the investigation included observation sheets, questionnaires, and tests. This study results in a conceptual framework for the instrument and a verified prototype of the Math-Sci competence evaluation. The Math-Sci competence evaluation is conceptualized around thematic, interdisciplinary questions that integrate three (three) subjects, namely Science (Biology-Physics) and Mathematics, in an Islamic context. Math-Sci, using the ladder analogy (monodisciplinary, interdisciplinary 1, and interdisciplinary 2) to rank students' competency, relates to the thought process of Bloom's taxonomy, the context, and the complexity of the topic. The instrument created was deemed valid and practicable based on the results of expert validation. The development of the Math-Sci competence assessment instrument was the first step toward strengthening assessment for learning and assisting in the improvement of learning through the presentation of integrated contextual problems.

Keywords: competence assessment; science and mathematics; 21st century competence; integrated with Islam

Abstrak

Pengembangan asesmen kompetensi yang membekalkan kecakapan abad 21 sangat urgent untuk memperbaiki proses pembelajaran di sekolah. Tulisan ini bertujuan mendeskripsikan framework dan prototype asesmen kompetensi Math-Sci untuk mengukur keterampilan abad 21. Metode penelitian pengembangan yang digunakan dalam penelitian ini mengacu pada framework Akker yang meliputi penelitian pendahuluan, prototipe yang meliputi desain, dan pengembangan dalam format paper and pencil test. Instrumen penelitian berupa lembar observasi, angket, dan tes. Hasil penelitian diperoleh kerangka konseptual instrumen dan prototipe asesmen kompetensi Math-Sci yang telah divalidasi melalui expert judgment. Kerangka konseptual asesmen kompetensi Math-Sci berupa soal-soal tematik, interdisipliner yang memadukan 3 (tiga) disiplin ilmu yakni IPA (Biologi-Fisika) dan Matematika pada konteks keIslaman. Math-Sci dengan analogi titian anak tangga (monodisiplin, interdisiplin 1, dan interdisiplin 2) yang mengukur kompetensi peserta didik secara hierarki mengacu pada proses berpikir taksonomi Bloom, konteks dan kompleksitas masalah. Hasil validasi pakar diperoleh instrumen soal yang dikembangkan valid dan layak. Pengembangan instrumen asesmen kompetensi Math-Sci merupakan langkah awal upaya menguatkan asesmen for learning, membantu memperbaiki pembelajaran, bersifat inovatif dengan menghadirkan permasalahan kontekstual integratif.

Kata kunci: asesmen kompetensi; matematika dan sains; kompetensi abad ke-21; integrasi dengan Islam

How to Cite: Zulfiani, Suwarna, I.P., Suwarna, Muin, A. (2021). Framework and Prototype Development of Mathsci Instruments for Measuring 21st Century Skills in Islamic Context. *TARBIYA: Journal of Education in Muslim Society*, 8(1), 96-107. doi:10.15408/tjems.v8i1.22120.

Permalink/DOI: <http://dx.doi.org/10.15408/tjems.v8i1.22120>

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Introduction

The Ministry of Education and Culture emphasizes the importance of increasing Indonesia's human resources to have a strong character, master 21st century competences, and be flexible to dynamics. The 21st century competence is oriented towards critical thinking for problem solving, creative thinking, communication and collaboration skills (Dede, 2010; Griffin & Care, 2014; Osman et al., 2013). These competences are often called 4C (4 competences) which are important to be provided to students from an early age, so that they can face the dynamics and globalization of the world in the future (Erstad & Voogt, 2018). To make it happen, Nizam (2018) states that improving the quality of learning is one of the strategies.

The concept of assessment for learning (AfL) in education can improve the quality of learning. Currently, AfL is a strategic issue (Schuwirth & Vleuten, 2011; Wiliam, 2011) correlated with the acquisition of student learning outcomes (Crisp, 2012). In today's learning reform, the concept of learning and assessment is faced with a new framework that needs to be synergized, which is by prioritizing the progress of potential and achievement of student competencies (Fook & Sidhu, 2015; National Research Council, 2014). However, the research results by Oogt & Roblin (2012) found a lot of harmony between the framework of what 21st century competencies are and their importance. However, it is still found that the intentions and practices are still far apart.

Efforts to make improvements and increase student competences need serious attention. One of the efforts is the Asesmen Kompetensi Siswa Indonesia/Indonesian Student Competence Assessment (AKSI) Program for Schools launched by the Ministry of Education and Culture. The AKSI program adapts the pattern used by PISA (Programme for International Student Assessment) as an effort to make improvements and increase student competence through formative assessment modules with the help of computer applications (Nizam, 2018).

The Ministry of Religious Affairs (Kemenag) as one of the other ministries that manages education needs to make the same effort to improve the competence of Islamic school (madrasah) students. The researchers together with the team submitted an AKSI-level application in the MIPA (Mathematics and Natural Sciences) subjects. Mathematics and Natural Sciences are subjects that are still an obstacle in quality in Islamic schools (Kusaeri & Ali Ridho, 2019). The application will be developed from the AKSI program, but it will have a different format. The difference lies in the new literacy elements, i.e., religion, information technology, and digital. Whitelock (2011) states that Web 2.0 tools can play a role in promoting the assessment agenda in learning. Tasks and assessment tools need to be embedded in a pedagogical framework that requires infrastructure support. The application will be developed based on the research results that the researchers and the team have done previously. The ScEd-ALS app hypermedia and android versions are science learning media, emphasizing embedding a pedagogical framework in applications (Zulfiani et al., 2021). Furthermore, in 2019 the Android version of the Science adaptive assessment application was developed. The development of the Math-Sci question instrument is the initial stage of assembling the Math-Sci 21st application.

Therefore, a Math-Sci question instrument model framework is needed, derived from the latest concepts/theories in line with the 21st century learning paradigm. The Math-Sci instrument conceptual framework is thematic, interdisciplinary, which combines three disciplines, namely Science (Biology-Physics) and Mathematics in an Islamic context. The development of the integration of Islamic

mathematical instruments is possible by taking into account the context and relevance of the concept (Kurniawati et al., 2018)

The development of the Math-Sci tool begins with the development of a question instrument framework, prototype, module preparation, and response feedback analysis. All stages will be carried out using the pencil and paper technique before the assembly stage of the Math-Sci application. Therefore, this paper aims to describe the results of developing a competence assessment framework and Math-Sci prototype that can measure 21st century competences in science and mathematics subjects for Year XI of Senior High School.

Method

The research method used is development research according to Akker's (2013) procedure. The research stages include preliminary research, prototyping stage, summative evaluation, and systematic reflection and documentation. This research resulted in a framework and prototype of the Math-Sci instrument in the form of a paper and pencil test so that the research stage was limited to two stages, i.e., (1) Preliminary research and (2) Prototyping stage. The next two stages; Summative evaluation and Systematic reflection and documentation, aim to produce a Math-Sci assessment application and show empirical evidence about the effectiveness and practicality of the developed application so that both stages will be implemented in the future.

In the preliminary research stage, the researcher led a literature study. The literature review carried out includes: (1) The analysis of related journals. (2) The identification of the concept of high school science and mathematics competency assessment. (3) Identifying the essential concepts of science and mathematics. The concept identification is carried out by analyzing the students' difficulties based on the results of the National Examination (UN) and the Basic Competence (KD) according to Permendikbud Number 37 of 2018. In addition, the selected material is adjusted to the results of mapping concepts that have a value below The Minimum Completeness Criteria (KKM) on the results of the 2019 National Examination (Pusat Penilaian Pendidikan Kemendikbud, 2019). Then set the material circulation system and respiratory system in biology; static fluids, wave mechanics, and work in physics; sequences and series, derivatives of functions, and trigonometry in mathematics. Next, the researcher analyzed the concept of scientific and Islamic integration according to the Qur'an/Hadith based on the material that had been determined.

In the prototyping stage, the researcher designed the framework and prototype of the Math-Sci instrument in a paper and pencil test. The framework and prototype of the Math-Sci assessment are thematic, interdisciplinary, which combines three disciplines, namely Science (Biology-Physics) and Mathematics in an Islamic context. The interdisciplinary thematic concept provides opportunities for more integrated questions to be presented, while the presentation of the verses of the Qur'an/Hadith as an Islamic context provides real experience to students that life is an interdisciplinary integration that will provide easy understanding of knowledge and its application in everyday life. Furthermore, the researchers validated the prototype on three material and learning experts so that a framework and prototype of the Math-Sci assessment were formed. To produce a more optimal Math-Sci application, researchers have compiled a draft of the Math-Sci application assembly in the form of a storyboard. The two stages of the research as described above are illustrated in Table 1.

Table 1. Research Stages in Formulating the Framework and Prototype of Math-Sci Instruments

Preliminary Research	Prototyping Stage
Literature study, including: <ul style="list-style-type: none"> • Journal analysis • Identify the concept of high school science and mathematics competency assessment • Identify essential science and math concepts • Analysis of the concept of scientific and Islamic integration 	<ul style="list-style-type: none"> • Design of frameworks and prototypes of Math-Sci instruments in the form of paper and pencil tests • Prototype validation • Math-Sci application assembly [draft]

The principle of assessment of the integration of science and mathematics in the Islamic context is an alternative assessment innovation with illustrations of stair steps in every aspect. The assessment questions developed refers to the cognitive processes of Anderson's (2001) and Puspendik (2015) revision of Bloom's Taxonomy, so that the operationalization of thinking processes is divided into three cognitive levels, namely: Level 1 (Knowledge and Understanding), Level 2 (Application), and Level 3 (Reasoning). The footbridge on the Math-Sci assessment prototype is divided into three, namely monodiscipline, interdisciplinary 1, and interdisciplinary 2. The first stage is in the form of questions that are monodisciplinary in an Islamic context. These prefix questions are in the form of biology questions with an Islamic context, physics with an Islamic context, or mathematics with an Islamic context. The prefix questions aim to measure students' understand of science and mathematics concepts in an Islamic context. This form of the question becomes a cross-check question on students' understanding, which will be compared with the questions at the next stage.

The second stage is in interdisciplinary question 1, which integrates two disciplines in an Islamic context. The format includes the integration of biology-physics with an Islamic context or the integration of biology-mathematics with an Islamic context or the integration of physics-mathematics with an Islamic context. Interdisciplinary Problem 1 aims to provide an integrated experience of 2 dimensions of science with an Islamic context as the foundation of more complex thinking. Furthermore, the culmination of this assessment is the question of interdisciplinary 2, namely the integration of three disciplines (Science (Biology & Physics) and Mathematics) in the Islamic context. Questions designed in interdisciplinary 2 can provide important information about higher-order thinking skills because all questions aim to measure cognitive levels at the L3 level.

This study uses two forms of questions: True-False with seven statements (a to g) and Multiple Choice with five options. The use of true-false questions aims so that students can evaluate the statements presented and classify true or false statements according to the answer key. Multiple-choice questions are a form of cross-checking questions against true-false questions which aim to ensure that students do not answer by guessing but understand the concept well. In addition, the two types of questions were chosen by considering the ease of problem construction in the Math-Sci application to be developed. The data analysis technique was carried out qualitatively based on the interpretation of the results of the instrument validation in the form of substance, construction, language, and criticism and suggestions from experts and quantitatively in the form of analysis of the average score on each aspect studied. Furthermore, the interpretation results are used as a reference for making revisions to produce a prototype of the Math-Sci thematic test instrument in Science and Mathematics.

Results and Discussion

Prototype of Math-Sci Problem Instruments

The Math-Sci instrument is thematic, interdisciplinary which combines 3 (three) disciplines, namely Science (Biology-Physics) and Mathematics, in an Islamic context. Thematic, interdisciplinary concepts provide opportunities for more integrated questions to be presented. The presentation of relevant Al-Quran/Hadith verses will not be measured but provides real experience to students of the connection and integration of every discipline in life.

The question domain is derived from the essential competencies of each subject. The question instrument consists of a test package that includes several specific topics totalling seven questions to be carried out for 1 hour of face-to-face learning. The Math-Sci instrument package with the analogy of a footbridge consists of 3 monodisciplinary questions, three interdisciplinary questions 1, and 1 interdisciplinary question 2. Stimulus questions are prepared by involving everyday problems in an Islamic context and focusing on the subjects to be tested. This study's Math Sci question package was designed for class XI SMA/MA students (Table 2).

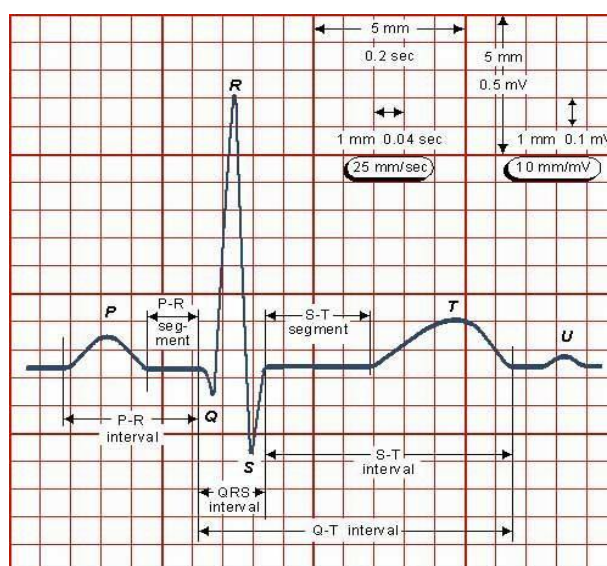
Table 2. Rubric for Basic Competence, Concepts, Indicators, and Context

Competence Base	Concept	Question Indicator	Cognitive Level	Context	Form	Question
Monodisciplinary						
3.6 Analyzing the relationship between the structure of the tissues that make up the organs in the circulatory system about bioprocesses and functional disturbances that can occur in the human circulatory system (Biology)	Human Circulation System	Providing integrated information from Hadith Bukhari no. 5641 regarding the symptoms of hypertension, students can apply the concept of measuring blood pressure.	Application(L2)	Islamic and personal	Multiple choice	1
Interdisciplinary 1						
3.6 Analyzing the relationship between the structure of the tissues that make up the organs in the circulatory system about bioprocesses and functional disturbances that can occur in the human circulatory system (Biology) 3.3 Applying the laws of static fluid in everyday life (Physics)	Human Circulation System, Fluid Continuity	Providing integrated information from Hadith Muslim no. 1967 regarding the symptoms of hypertension, students can analyze the characteristics of hypertension associated with fluid continuity.	Reasoning (L3)	Islamic and personal	True False	2
Interdisciplinary 2						
3.6 Analyzing the relationship between the structure of the tissues that make up the organs in the circulatory system in relation to bioprocesses and functional disturbances that can occur in the human circulatory system (Biology) 3.3 Applying the laws of static fluid in everyday life (Physics) 3.6 Explain composition operations on functions and inverse operations on inverse functions and their properties and determine their existence (Mathematics)	Human Circulation System, Hydrostatic Pressure, Invers	Providing integrated information from the verses of the Qur'an QS. At-Taghabun : 11, regarding the effect of aquades on blood vessels, students can analyze the cause-and-effect relationship of the event.	Reasoning (L3)	Islamic and personal	True False	3

The following is an example of an interdisciplinary question instrument in True-False, integrating two disciplines (Biology and Physics) in an Islamic context. Stimulus questions are arranged thematically regarding the function of the circulatory organs and recordings of heartbeats with relevant Islamic contexts; then, students must analyze the mechanism of impulse propagation in the heart associated with mechanical waves. Furthermore, the questions are arranged in the form of seven true or false statements by integrating the concepts of biology (circulation system) and physics (wave mechanics).

Interdisciplinary 1

1. Allah says in Surah Qaf verse 16, which means, "And indeed We have created man and know what the heart whispers and We are closer than his jugular vein." The verse shows a sign of God's greatness, namely the existence of blood vessels and the heart that can conduct electricity so that life can run normally. The following is a recording of the heart rate based on the EKG (electrocardiogram).



The statement that corresponds to the information presented in the question is...

Question	True	False
a) The atrioventricular node can withstand impulses to allow filling of the ventricles as the atria contract.	√	
b) The fastest time it takes the heart to close to produce one wave takes about 0,08 seconds, followed by another slight vibration.	√	

Expert Validation Results

Three experts validated the Math-Sci instrument. There are several components in material expert validation and the following below are the results of expert validation (Table 3). Analysis of the items was carried out qualitatively, covering aspects of material, construction, language, and additional rules and quantitatively in the form of analysis of the average score for each aspect studied. The material aspect focuses on the scientific substance of Science and Mathematics and the cognitive level to be studied. The construction aspect focuses on matters relating to the rules of writing questions. The language aspect focuses on using good and correct Indonesian

according to standard rules, while the additional regulatory aspects relate to elements of (Ethnicity, Religion, Race), Intergroup, Pornography, Politics, Propaganda, and Violence (SARAPPPK).

Table 3. Expert Validation Results for Math-Sci Instrument Materials

No.	Reviewed Aspects	Average Score			Overall Average
		Validator 1	Validator 2	Validator 3	
1.	Material	4,85	4,85	4,75	4,81
2.	Construction	5	4,5	4,33	4,61
3.	Language	5	4,75	5	4,91
4.	Additional rules	5	5	5	5
Average		4,96	4,77	4,77	4,83
Interpretation		Very good	Very good	Very good	Very good

The validation results show that the overall items are very good because the questions are following basic indicators and competencies, according to the cognitive level to be achieved, namely reasoning (L3), the scope of STEM (mathematics, physics, biology) is fulfilled, brings novelty and encourages students to read and search for relevant libraries to find answers, and do not contain elements of SARAPPPK. The indicators for each aspect as a whole get a score of 5 (very good).

The use of language, when viewed from the communicative side, is classified as good because there is the use of Latin in some questions, but when viewed from the side of fulfilling the achievement in the field of biology, it is classified as very good. Suggestions given by the validator include: (1) The language aspect of some questions needs to be improved so as not to give doubts when answering questions. (2) The need for a proportional comparison of questions between mathematics, physics, and biology. (3) If necessary, thematic questions related to chemical concepts can be added. (4) It is necessary to check several concepts in high school material related to the conversion of mmHg to Pascal, or calculations regarding the relationship of blood vessel diameter to the driving force of blood flow, as well as how to read an electrocardiogram (ECG) graph so that the questions given are following the cognitive level of students.

The analysis of journals and literature shows that competency assessment plays a crucial role in optimizing the educational process and increasing the education system's effectiveness. However, to adequately assess competence in educational settings is a challenging undertaking. Leutner et al. (2017) stated that adequate competence assessment, both theoretical and empirical in education management, is often underestimated by policymakers and practitioners.

The ATC21S assessment view sees the practice as if it has fallen far behind in the global environment. The course of learning and testing in schools with the contemporary world of work shows a marked difference. Subjects in schools today are separated by disciplinary boundaries, but in the world of work, the subject of application crosses disciplinary boundaries. The main problem facing the world of work is complex and unstructured (Wilson & Scalise, 2015). Osborne's (2013) research emphasizes the importance of finding a good scientific reasoning model that can assess high-level cognitive competencies even though low cognitive demands still dominate school science education.

The principle of integration in the Math-Sci assessment is carried out while still fulfilling the principles of integration, namely in context, relevance, and some lessons/experiences that are beneficial to students. The presentation context is interdisciplinary contextual thematic and fulfills the integration of subjects to measure students' competence. The value of Islam as a context in the problem is not to be measured. This integration is a meaningful effort so that students can find linkages to concrete problems whose dimensions are more comprehensive. Islam as the context of the problem posed has positive implications. Students when studying these sciences not only increase their knowledge, but have implications for awareness of God and improve morals (Muspiroh, 2016).

The principles of cohesiveness, contextual problem solving, and competency achievement in the Math-Sci assessment accommodates the basic principles of STEM learning (Science, Technology, Engineering, and Mathematics). This is shown in the stimulus for Math-Sci questions, which are constructed as a narrative in daily life problems with a STEM scope equipped with tables/pictures/graphs as a medium of thinking for students. STEM learning is 21st century learning with advantages in integrating concepts, principles, applications of science, technology, engineering, and mathematics in the development of knowledge. In addition, STEM can direct students in finding solutions that can be used in everyday life (Bakirci & Karisan 2018; Gonzalez & Kuenzi 2012) and holds the principles of meta-discipline, solutions to barriers to integration, focusing on innovation (Kennedy & Odell, 2014). Bujuri et al. (2018) who emphasize contextual-based integrative science teaching materials believe that it will be able to actualize knowledge that is useful for everyday life. Problem-solving ability is one of the high-level skills strongly emphasized in the 4C skills and innovation learning skills (Afandi et al., 2019; Widana et al., 2018). Thus, the Math-Sci assessment becomes an alternative competency assessment that supports the implementation of STEM-based learning.

The value of the novelty of this assessment lies in the construction of the Math-Sci framework, in which the form of the step-by-step questions is the monodisciplinary format, interdisciplinary 1, interdisciplinary 2. The monodisciplinary format is a cross-check question of fundamental understanding juxtaposed with a more complex interdisciplinary format, both at the level of thinking and the problem. So, the tiered Math-Sci format adjusts to the level of thinking and the complexity of the problem. As a diagnostic tool, Math-Sci assessment can obtain information on student progress in a hierarchical manner. Interdisciplinary question 1 integrates two disciplines in an Islamic context aimed at providing an integrated experience 2.

Dimensions of science with an Islamic context as the foundation of more complex thinking. The concept of integration of Mathematics and Natural Sciences (interdisciplinary 2) is the ultimate assessment to be achieved so that it can provide important information in terms of students' higher-order thinking skills. However, if this achievement is not achieved, then the student's performance can still be known through the ladder's rungs, both monodisciplinary and interdisciplinary.

The Math-Sci Instrument Format can also measure higher-order thinking skills because the instrument settings can be arranged in the cognitive process of analyzing to creating (C4-C6), for example, like the prototype presented above. Thus, the Math-Sci instrument considers the

urgency of higher-order thinking skills which are essential in today's innovative assessment principles (Ichsan et al., 2020; Saputri, 2019).

The Math-Sci instrument can also measure 21st century skills known as 4C Competencies (Creative, Critical, Communication, and Collaborative). The development of instruments oriented to higher-order thinking processes demands complex skills. Students not only discover but also evaluate, synthesize, and use knowledge in new contexts. All of which require student competence in progressive thinking processes, non-routine problem solving, and communication (Widana et al., 2018; Zulfiani et al., 2020). The implications of learning with the HOTS assessment module in sixth-grade elementary school children can better guide students to think critically in solving problems (Kurniawan & Utaminingsih, 2021).

The three formats adapted to the purpose of the product to be designed are the Math-Sci application. Therefore, the format of the questions is adjusted, i.e., using True and False, Multiple Choice, and Short Answer forms. Consideration of processing time is needed to ensure that this instrument can be used by the teacher in learning. The validation results show that the Math-Sci instrument is feasible to be tested empirically. In the next research study, researchers can continue assembling the Math-Sci Application which is useful as a diagnostic tool for Year XI students where the results of this assessment can provide feedback to teachers and make learning better, innovative, and fun.

Conclusion

Efforts to improve the quality of education can begin by synergizing learning and assessment. This preliminary research is an effort to develop a Math-Sci application for science and mathematics competence assessment to measure 21st century skills. The first step is to find a competence assessment framework and design a prototype instrument. The Math-Sci framework is designed thematically for Islamic values-integrated science and mathematics. This thematic concept provides an opportunity to make the context of the questions more integrated and relevant Qur'an/Hadith references to the topic to be raised were selected. The presentation of the Qur'an/Hadith will not be measured, but it provides real experience to students that life is an interdisciplinary integration that will provide easy understanding of knowledge and its application in everyday life. The prototype of the Math-Sci instrument was then validated by material experts and obtained valid and worthy questions to be tested.

Acknowledgement

The researchers extend their gratitude to PUSLITPEN LP2M UIN Syarif Hidayatullah Jakarta for the 2021 interdisciplinary basic research grant.

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