An Ethnoastronomy Learning Progression (eALP): Scientific Literacy Skills As The Progress Dimensions

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Abstrak. Astronomy which studies natural phenomena related to the motion of celestial bodies is one of the study materials that undergraduates in science education need to master. In this digital era, to study the relative motion of celestial bodies observed from the earth, various skills are needed and supported by the right technology. The author proposes scientific literacy skills as a dimension of progress in the ethnoastronomy learning progression of the earth's seasons for the science program undergraduate program. Scientific literacy skills have three dimensions, namely scientific concepts, scientific process, and scientific context. Scientific concepts are needed to understand the phenomenon of changing seasons on earth with the support of the Stellarium application. Scientific processes are centered on the ability to obtain, interpret, and act on evidence of the phenomenon of changing seasons on earth in five scientific processes, namely recognizing scientific questions, identifying evidence, drawing conclusions, communicating conclusions, and demonstrating scientific understanding. Scientific context can be bridged through ethnoastronomy related to seasonal changes by studying the regional calendar/student residence, for example, *Pranatamangsa*. Students' astronomical learning progress can be defined by the increasing sophistication of their scientific literacy skills. An ethnoastronomical learning progression (eALP) framework has been developed and discussed in this paper.

Key words: Astronomical learning progession, ethnoastronomy, seasons, scientific literacy

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INTRODUCTION

Scientific literacy is one of the basic skills that every child and young person needs to master as a target for the Sustainable Development Goals (SDGs) in the education sector of every country by 2030 (United Nations, 2017). To measure the achievement of these targets, the Organization for Economic Cooperation and Development (OECD) has designed the Program for International Student Assessment (PISA) to assess the reading, math and science skills of students who are close to completing primary education (OECD, 2019b). PISA assessed science content knowledge is selected from the key areas of physics, chemistry, biology, and earth and space sciences (OECD, 2019b). The minimum level of competence is the level of ability to solve problems that require a minimum ability equivalent to international standards and show the characteristics of independent thinking. The same level of competence is also used in monitoring the target of Sustainable Development Goals (SDGs) in the education sector point 4.1. In other words, the minimum level of competence can be an indicator of a country's success in providing education (OECD, 2019a). The PISA survey looked at literacy levels in reading, mathematics, and science in the population of 15-year-old schoolchildren in participating countries and compared their competencies (OECD, 2019a). PISA is carried out on a quarterly basis from 2000 to the present to evaluate education systems around the world (OECD, 2019a).

PISA 2018 results show on average across OECD countries, 78% of students achieve Level 2 or higher in science (OECD, 2019c). However, the 2018 PISA Report for Indonesia shows that only 34% of students have a minimum level of science competence or above (OECD, 2019a). Referring to the Caroll model which describes the relationship between student learning time and academic achievement, the time spent on science lessons by Indonesian students has a positive relationship with the acquisition of PISA scores (OECD, 2019a). Learning science in Indonesian schools has the least time allocation compared to mathematics and language. As a result, science learning tends to be delivered widely but not studied in depth so that students find it difficult to apply scientific content in everyday life. These results indicate that science learning has not had a significant impact on students and society. One of his recommendations is that Indonesia still needs to improve the quality and quality of education through improving the quality of teachers (OECD, 2019a).

The science education department can also play a role in preparing qualified science teacher candidates. Undergraduates of science education department need to be equipped with good scientific literacy competencies. In addition, the Science education department also needs to prepare prospective science teachers who are not only capable of teaching, but also able to help students develop a reliable compass to navigate an increasingly complex, ambiguous, and volatile world.(OECD, 2020). Prospective science teachers also need to be equipped with culture-based science education and digital technology to be able to prepare students to thrive in a connected world (OECD, 2020). The lack of learning time in science learning also needs to be addressed. Earth and space science science content trending the least learning time in most countries (Plummer & Maynard, 2014). Caroll found that the time required to learn affects the availability of study time, the ability to understand instructions, instructional quality, and desire to learn (OECD, 2019a). One of the new ways promoted for the improvement of science teaching and learning in the Next Generation Science Standards (NGSS) is learning progressions (LPs) (Carpenter et al., 2020; Fulmer et al., 2018; Kaldaras et al., 2021; Lei Liu et al., 2013).

Learning progressions are defined as empirically based and testable hypotheses about how students' understanding of, and ability to use, core scientific concepts, explanations, and scientific practices relate to the development of sophistication of thinking over time using appropriate instruction (Lei Liu et al., 2013). Basically, an LP is a roadmap showing how a student's qualitative understanding of a particular idea or practice is likely to change over time with appropriate instruction. Therefore, LPs can serve as a guide for educators as they design instruction and monitor student progress toward targeted levels of understanding and ability (Lei Liu et al., 2013). Learning progressions related to environmental scientific literacy have been developed by Gunckel (2012) presenting the relationship between knowledge, practice, and knowledge (Gunckel et al., 2012). Plummer has also developed learning progressions in physics and astronomy (Plummer et al., 2020; Plummer & Maynard, 2014). Learning progressions in science learning are related to culture, digital technology in the scientific literacy domain is relevant for further research. Research question of this study is How students' astronomical learning progress can be defined by the increasing sophistication of the scientific literacy skills? This study is important as an effort to improve the quality of science education through the preparation of qualified science teacher candidates, literate science-culture-digital technology through appropriate instructional stages.

METHODS

This study uses an evaluation research approach with modified educational research and development research methods (Gall, 2003). The stages of this study include preliminary studies, literature studies and development stages. In the preliminary study stage, the researcher examines the literature related to science education evaluation research to formulate the research question that is reviewed in the Introduction section of this article. Next, the researcher reviewed the literature and carried out development. The results of the literature study and development are presented in the results and discussion section in three subchapters: organization of the scientific literacy domain framework of PISA 2018, knowledge dimension of astronomical phenomena of Earth's Seasons, and scientific literacy skills as the progress dimension in ethnoastronomical learning progressions of the Earth's seasons framework.

RESULTS AND DISCUSSION

This section will answer the research question about How students' astronomical learning progress can be defined by the increasing sophistication of the scientific literacy skills? First, the researcher will present the results of the literature review on the conceptual framework of scientific literacy. Second, the researcher will present the results of a literature review on astronomical observable phenomena about seasonal changes. Third, the researcher presents the results of developing an ethnoastronomical learning progression with scientific literacy as a dimension of progress to answer research questions.

Organisation of the scientific literacy domain framework of PISA 2018

PISA is a special assessment that helps international comparisons of education systems between countries through the use of the same questions and the same scale by all participating countries. The PISA design and approach is optimized to obtain an estimated score at the system level. In each area, the PISA report divides students' scores into six proficiency levels. Questions with the same level of difficulty are used to describe each level of proficiency. In the context of what students know and can do with their knowledge based on the position of students' scores in the range of proficiency levels. Thus, the performance of the education system that is read through PISA can be described well, especially with regard to the skills and knowledge that students are able to master at the age of 15 years. so that it gives a much more complete picture than an assessment based on numbers or ratings. PISA is an ongoing program that in the long term produces a collection of useful information in monitoring trends in students' knowledge and skills in various countries as well as in various demographic groups of each country. Policy makers around the world use PISA findings to measure the knowledge and skills of students in their respective countries and compare them with the knowledge and skills of students in other PISA participating countries to set benchmarks for quality improvement in education provision and learning outcomes, and understand the strengths and weaknesses of each education system (OECD, 2019a). The PISA 2018 scientific literacy domain organization is shown in table 1.

Table 1. Scientific literacy domain of PISA 2018 framework

Scientific literacy aspects	Componens
Contexts	Personal Local/national Global
Knowledge	Content Procedural Epistemic
Competencies	Explaining phenomena scientifically Evaluating and designing scientific enquiry Interpreting data and evidence scientifically

Based on table 1, the PISA 2018 scientific literacy assessment domain framework is based on 3 aspects, namely three types of context, three types of knowledge, and three types of competencies. PISA 2018 assesses scientific knowledge using contexts that raise related issues that are often relevant to the science education curricula of participating countries. However, assessment items are not limited to the context of school science. Items in the 2018 PISA science assessment can relate to self, family and peer groups (personal), to community (local and national) or to life around the world (global). The context may involve technology or, in some cases, elements history that can be used to assess students' understanding of the processes and practices involved in advancing scientific knowledge (OECD, 2019b). Table 1 also shows the types of competencies in scientific literacy used in PISA 2018. Scientific literacy competencies in PISA 2018 include the ability to explain phenomena scientifically, the ability to evaluate and design scientific research, and the ability to interpret data and evidence scientifically. This collection of scientific competencies reflects the view that science is best seen as an ensemble of social and epistemic practices common in all its subfields (NRC, 2012). All these competencies require knowledge. The types of scientific knowledge used in PISA 2018 include content knowledge, procedural knowledge, and epistemic knowledge. Content knowledge is required in explaining scientific phenomena. Procedural knowledge is needed in recognizing and identifying the characteristics of scientific investigations about standard procedures that underlie the selection of methods and practices used to build scientific knowledge. While epistemic knowledge is an understanding of the reasons for the general practice of scientific inquiry, the status of the resulting claims, and basic meanings such as theories, hypotheses, and data.

Knowledge dimension of astronomical phenomena of the Earth's seasons

The change of seasons is a key phenomenon of celestial motion. Extensive research has shown that most people cannot accurately describe the seasons. The most common non-normative explanation is that the earth is moving closer and further away from the sun (Plummer & Maynard, 2014). Moreover, the lack of understanding that the apparent daily path of the sun changes throughout the seasons (Plummer et al., 2020) and the non-normative belief that the Earth's orbit is highly elliptical (Plummer et al., 2020)contribute to the difficulty that children have in learning to explain the seasons. Recent studies documented having a successful instructional approach to teaching explanations for seasons (Plummer & Maynard, 2014). Plummer (2014) has investigated how students learn to move between frames of reference, how instruction can support students in constructing upward sophistication with respect to development, and how instruction supports connections across constructs (between phenomena) in their development (Plummer & Maynard, 2014), describes the two studies we used to determine the daily level of celestial motion and the seasons to map in them the big idea of celestial motion. Based on these studies, the researchers then grouped the knowledge dimensions of the seasonal change phenomenon as presented in Figure 1.

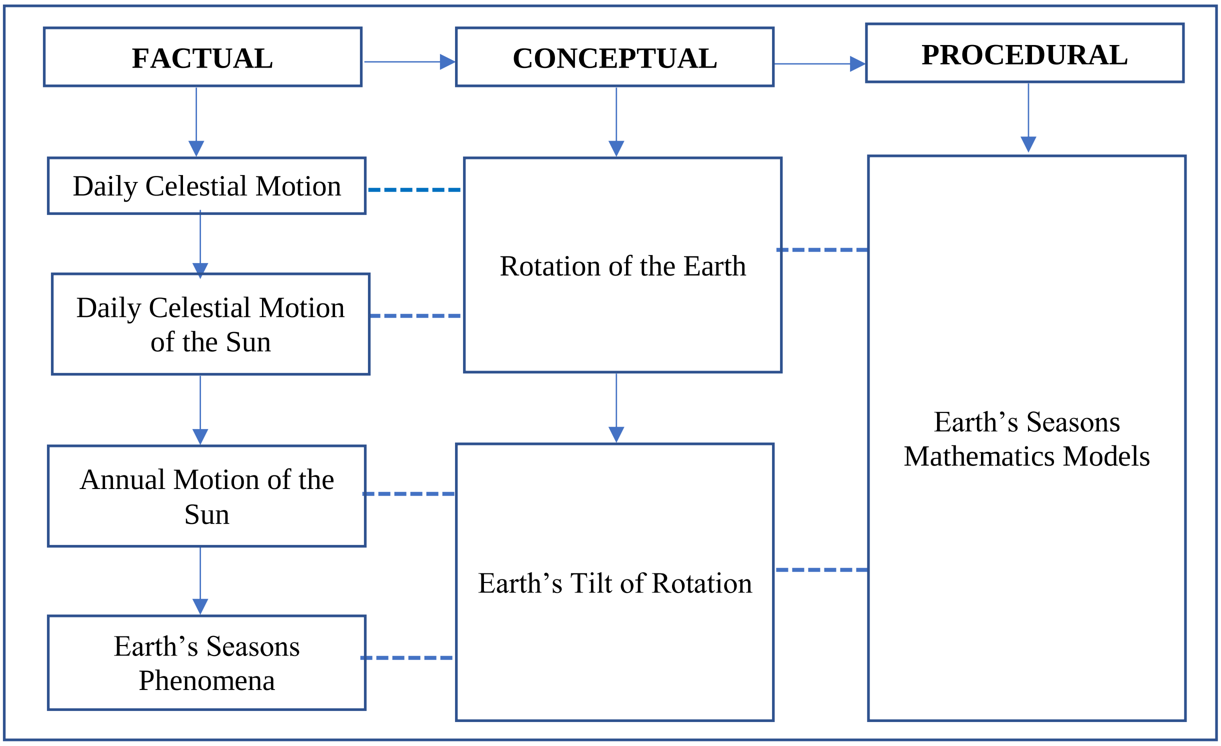
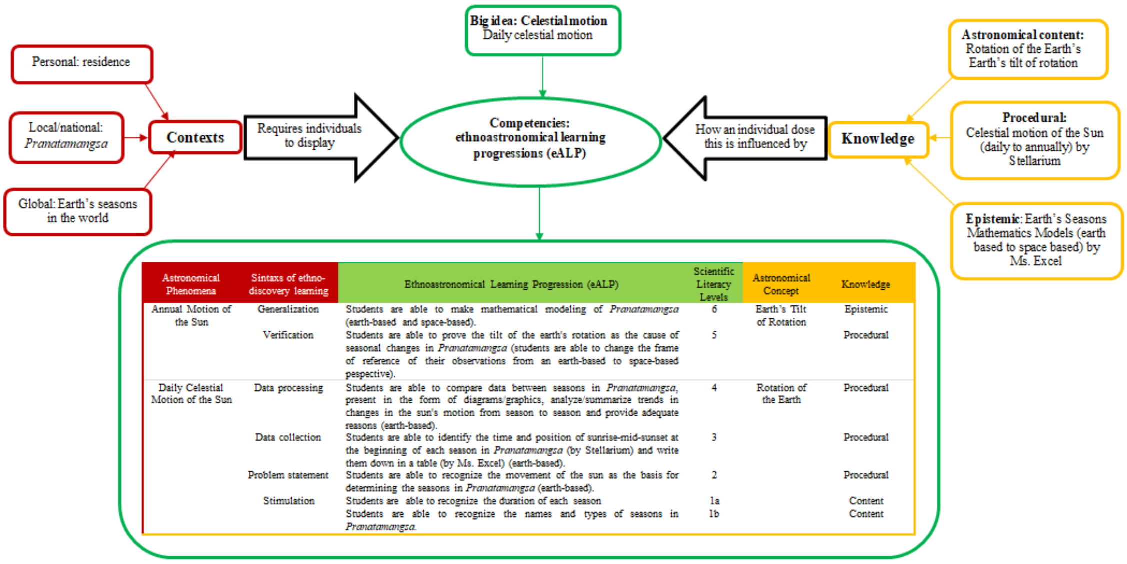


Figure 1. Knowledge Dimension of Astronomical Phenomena of the Earth's Seasons

Researchers categorize the dimensions of knowledge of astronomical phenomena about seasonal changes based on the dimensions of knowledge according to Anderson and Krathwoll including factual, conceptual, procedural, and metacognitive dimensions that show cognitive complexity (Ariyana et al., 2018; Fick, 2018; Rao, 2020; Rivalina, 2020). Based on figure 1, the researcher divides the astronomical phenomenon of seasonal changes into three dimensions of knowledge (Kubiatko et al., 2021). Dimensions of factual knowledge include daily celestial motion, daily celestial motion of the Sun, annual celestial motion of the Sun as an estuary in explaining facts related to Earth's seasons phenomena. Furthermore, the dimensions of conceptual knowledge in seasonal changes include the rotation of the earth and the tilt of the earth's rotation. At the end, procedural knowledge is required to create Earth's season mathematics models.

Scientific literacy skills as the progress dimension in ethnoastronomical learning progressions of the Earth's seasons framework

Astronomy which studies natural phenomena related to the motion of celestial bodies is one of the study materials that undergraduates in science education need to master. In this digital era, to study the relative motion of celestial bodies observed from the earth, various skills are needed and supported by the right technology and appropriate instructions within the framework of astronomical learning progressions.



Astronomical Phenomena	Sintaxs of ethno-discovery learning	Ethnoastronomical Learning Progression (eALP)	Scientific Literacy Levels	Astronomical Concept	Knowledge
Annual Motion of the Sun	Generalization	Students are able to make mathematical modeling of *Pranatamangsa* (earth-based and space-based).	6	Earth's Tilt of Rotation	Epistemic
	Verification	Students are able to prove the tilt of the earth's rotation as the cause of seasonal changes in *Pranatamangsa* (students are able to change the frame of reference of their observations from an earth-based to space-based pespective).	5		Procedural
Daily Celestial Motion of the Sun	Data processing	Students are able to compare data between seasons in *Pranatamangsa*, present in the form of diagrams/graphics, analyze/summarize trends in changes in the sun's motion from season to season and provide adequate reasons (earth-based).	4	Rotation of the Earth	Procedural
	Data collection	Students are able to identify the time and position of sunrise-mid-sunset at the beginning of each season in *Pranatamangsa* (by Stellarium) and write them down in a table (by Ms. Excel) (earth-based).	3		Procedural
	Problem statement	Students are able to recognize the movement of the sun as the basis for determining the seasons in *Pranatamangsa* (earth-based).	2		Procedural
	Stimulation	Students are able to recognize the duration of each season	1a		Content
		Students are able to recognize the names and types of seasons in *Pranatamangsa*.	1b		Content

Figure 2. Scientific literacy skills as the progress dimension in Ethnoastronomical Learning Progressions of the Earth's Seasons Framework

A learning progression is a roadmap showing how the quality of a student's understanding of a particular idea or practice is likely to change with appropriate instruction(Leu Liu & Jackson, 2019). One of the initial stages in developing learning progression is the selection of a big idea from a phenomenon that is in harmony with scientific content(Leu Liu & Jackson, 2019; Plummer, 2014; Plummer & Maynard, 2014). Therefore, the big idea in this study reproduces Plummer's findings about celestial motion(Plummer, 2014; Plummer & Krajcik, 2010; Plummer & Maynard, 2014). If Plummer (2014) uses spatial thinking as a dimension of progress towards the sophistication of students' thinking, then in this study the researcher uses scientific literacy ability as a dimension of progress. Our next step in defining learning progress is to find ways for students to incorporate aspects of celestial motion in their explanations of more advanced phenomena (seeing both horizontally and vertically in learning) as shown in Figure 2. Ethnoastronomical learning progressions of the Earth's season framework is defined by integrating the knowledge dimension of the seasonal change phenomenon in Figure 1 and the organization of scientific literacy domain in Table 1. The construct map for daily celestial motion (Figure 1) illustrates the increasing sophistication in using the Earth's rotation to explain observable phenomena. A full understanding of the daily celestial motion is not a precursor to other constructs; rather, aspects of everyday life link celestial motion to other construction maps as prerequisite knowledge.

According to Plummer (2014) in building an understanding of how students learn to explain the daily motion of the sky, as a prerequisite for investigating students' explanations of how the apparent motion pattern of the sun causes the seasons.(Plummer & Maynard, 2014). Plummer studied eighth graders who studied both patterns in terms of an earth-based perspective and explanations for the patterns. Using the Rasch modeling approach, we identified a sequence of concepts potentially related to the seasons, from easiest to most difficult. Based on this quantitative analysis, we identified a set of levels that describe the increasing sophistication that defines the construction map for the season. Very few students achieve this level of scientific progress. The reason may be, in part, that many students have not achieved a strong mental model of the sun-earth part of the daily celestial motion construction map, a prerequisite for the top-level season construction map. Without a complete understanding of the apparent motion of the sun (Plummer & Maynard, 2014).

The ethnoastronomical learning progression of the Earth's seasons framework is presented in a personal, local/national, and global instructional context. In a personal context, students are expected to be able to identify the changing seasons in the area where they live (residence). In the local/national context, it is the entry point for culture (ethno). Through the ethno-discovery learning model, the local calendar is used to stimulate students' thinking about changing seasons on a local/national scale. The researcher gives an example of the use of *Pranatamangsa*, namely the seasonal calendar of the Javanese people, Indonesia. Students are expected to be able to recognize the changing seasons after reading and make simple interpretations of *Pranatamangsa*. In a global context, students are introduced to the changing seasons in various parts of the world.

Competence in scientific literacy in ethnoastronomical learning progression is used as a dimension of student learning progress. Three scientific literacy competencies were then made scaffolding in seven levels of ethnoastronomy abilities which were presented vertically. Every increase in the level of scientific literacy means an increase in sophistication in the understanding of ethnoastronomy. The progress of individual student learning progress is influenced by the three knowledges they have, namely astronomical content, appropriate evidence-finding procedures, and epistemic knowledge to the status of the resulting claims. For these three processes, most of the evidence is obtained digitally, thus requiring knowledge of digital content and digital literacy as well. Therefore, students can understand observable astronomical phenomena of the Earth's seasons in the dimension of scientific literacy sophistication.

CONCLUSION

Based on the findings discussed above, students' astronomical learning progress can be defined by the increasing sophistication of the scientific literacy skills which consists of three individual-local/national-global contexts, three content-procedural-systemic knowledge, and three competencies. The first is the ability to provide explanations about natural phenomena, technical and technological artifacts and their implications for society. Second, the competence to use knowledge and understanding of scientific inquiry to identify questions that can be answered by scientific inquiry; propose ways in which such questions might be addressed; and identify whether appropriate procedures have been used. the third is the competence to interpret and evaluate data and evidence scientifically and evaluate whether the conclusions can be justified. These scientific literacy competencies are distributed in seven levels of ethnoastronomy learning progress of the Earth's seasons. Further research needs to be conducted to find empirical evidence of the development of the eALP.

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