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STUDENTS' LEARNED KNOWLEDGE OF THE CONCEPT OF ANGLE AND ANGULAR MEASURE: A DIDACTIC TRANSPOSITION PERSPECTIVE

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ABSTRACT The concept of angle and angular measure are essential concepts that need to be well understood in learning geometry. However, students often misunderstand these concepts. This study aimed to analyze how the shift in knowledge of the concept of angle and angle measurement in the perspective of didactic transposition. A qualitative study with a phenomenological approach was conducted to examine this phenomena. Data were collected through classroom observation, interviews, and documentation studies. The results of the study indicate that the transposition process in learning affects students' conceptualization process of the definition of angles so that students cannot distinguish between angles and anglular measure and tend to consider the two to be the same. A weak transposition process often causes errors, variations in meaning, and limited knowledge. This study emphasizes the need for a good didactic approach to bridge the gap in the transition process between scientific knowledge of mathematics and students' understanding. The implications of this study suggest that there is an alignment of both the curriculum and teaching materials that are in line with scholarly knowledge to improve students' understanding of the concept of angles and anglular measure.

Keywords: angle, angular measure, didactic transposition, geometry.

ABSTRAK Konsep sudut dan ukuran sudut merupakan konsep-konsep esensial yang perlu dipahami dengan baik dalam belajar geometri. Namun, mahasiswa sering kali salah dalam memahami konsep-konsep tersebut. Penelitian ini bertujuan untuk menganalisis bagaimana pergeseran pengetahuan konsep sudut dan ukuran sudut dalam perspektif transposisi didaktis. Sebuah studi kualitatif dengan pendekatan fenomenologi dilakukan untuk mengkaji hal itu. Data dikumpulkan melalui observasi kelas, wawancara, dan studi dokumen. Hasil penelitian menunjukkan bahwa proses transposisi dalam pembelajaran memengaruhi proses konseptualisasi mahasiswa tentang definisi sudut sehingga mahasiswa tidak bisa membedakan antara sudut dan ukuran sudut serta cenderung menganggap dua hal itu sama. Proses transposisi yang tidak baik sering kali menyebabkan kesalahan, variasi dalam pemaknaan, maupun pengetahuan yang terbatas. Penelitian ini menekankan perlunya pendekatan didaktik yang baik untuk menjembatani kesenjangan dalam proses transisi antara pengetahuan ilmiah matematika dengan pemahaman mahasiswa. Implikasi dari penelitian ini menyarankan adanya suatu keselarasan baik dari kurikulum maupun bahan ajar

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yang sejalan dengan scholarly knowledge untuk meningkatkan pemahaman mahasiswa tentang konsep sudut dan ukuran sudut.

Kata-kata kunci: geometry, sudut, transposisi didaktis, ukuran sudut

INTRODUCTION

One essential component of geometry that students need to grasp thoroughly is the idea of angles and angular measure. A proper understanding of this concept is very important because it is the basis for various other mathematical topics, such as trigonometry, analytical geometry, and calculus. Therefore, in various geometry textbooks, this concept is presented at the beginning. However, various studies have shown that students often have difficulty distinguishing between angles and angular measure. This conceptual error may originate from the way the concept is transformed from academic knowledge into teaching and learning materials in the classroom, a process known as didactic transposition (Chevallard, 2019; Chevallard & Bosch, 2020). Chevallard (1989) stated that didactic transposition was transpositional knowledge between mathematical knowledge that was produced by mathematicians (scholarly knowledge), mathematics that must be taught based on the curriculum (knowledge to be taught), knowledge of mathematics that was taught (taught knowledge), and knowledge of mathematics that was learned (learned knowledge) (See Figure 1). In this process, scientific knowledge often undergoes adaptations that do not always maintain the essence of the original concept, which can lead to misconceptions among students.

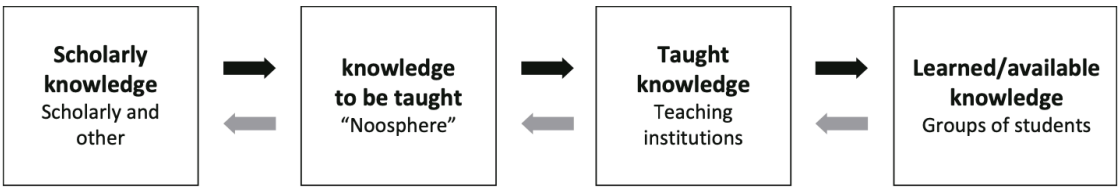

Figure 1. Didactic Transposition Process (Marianna Bosch & Gascón, 2006; Chevallard & Bosch, 2020)

From a didactic perspective, several studies have explored how didactic transposition affects students' understanding of various mathematical concepts. The concept of didactic transposition introduced by Chevallard has been used in many studies to analyze how mathematical concepts change when moving from academic knowledge into the curriculum and classroom learning. Some research included didactic transposition of the concept of concavity of functions ((Strømskag & Chevallard, 2024), straight-line equations (Suarsana et al., 2024), fundamental theorem of calculus (Topphol, 2023), the concept of limit (Sulastri, 2023), natural number (Henriksen, 2022), set theory (Jamilah et al., 2021, 2020), external didactic transposition in undergraduate mathematics education (Bosch et al., 2021), didactic transposition reflection within Reflective Practice of an Indonesian Mathematics

Teacher Community (Rudi et al., 2022) and central angle and circumferential angle of a circle (Winarji & Turmudi, 2020). In the context of geometry, several studies have highlighted how simplification or distortion in teaching materials can lead to conceptual errors among students, for example, research by Herizal & Priatna (2024) looked at how weak transposition processes can result in students' misunderstanding of the topic of angles formed when two lines are cut by a transversal. However, studies that specifically analyze didactic transposition on the concept of angles and angular measure are still limited, especially in the context of higher education.

A good didactic transposition process will impact on providing right mathematical concepts, and forming of appropriate learning situations (Jamilah et al., 2020). On the other hand, a less than optimal didactic transposition process can cause various problems in learning, such as oversimplification of concepts or the use of inconsistent definitions. This has an impact on students' misunderstanding and tends to cause epistemological obstacles, namely learning obstacles caused by limited context in the initial introduction process (Brousseau, 1997; Suryadi, 2019). If this is not understood properly, the problem solving process will also be problematic, because understanding the concept will affect the student's process in solving problems (Herizal et al., 2019). In addition, another problem that arises if the transposition process is not good is the difference between the concept image and the concept definition (formal definition) of a mathematical concept. In fact, according to Tall & Vinner (1981) and Vinner (2020), concept images can include "all the mental pictures and associated properties" that students form over time through problem-solving, visual representations, and classroom discussions. Due to the importance of both angle and angular measure concepts and didactic transposition, a study was conducted to analyze the didactic transposition process on the concepts. This study was focused on two step of didactic transposition which were scholarly knowledge and learned knowledge. Therefore, this study aimed to analyze how a concept changes, especially the concept of angles and angular measure. By understanding the pattern of knowledge shifts that occur, it is hoped that this study can provide insight into how more effective teaching material can be developed to avoid students having a misconception about a concept.

METHODS

This study used a qualitative approach with a phenomenological method to analyze the phenomenon of how knowledge changes, in this case the concept of angles and angular measure, from the didactic transposition process from scholarly knowledge to learned knowledge. The use of qualitative method because qualitative research was considered to provide an in-depth description of a particular program, practice, or setting (Mertens, 2020). Furthermore, the use of phenomenology as the design research because phenomenological research was a design which the researcher

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describes the lived experiences of individuals about a phenomenon as described by participants (Giorgi, 2009; Moustakas, 1994).

The subjects of the study consisted of early semester students of the mathematics education study program at a state university in Aceh who were studying basic geometry (N=32). Data were collected through classroom observations to observe learning interactions, semi-structured interviews with students to explore their understanding of the concept, and document analysis including geometry textbooks and school mathematics books. The data obtained were analyzed thematically to identify patterns of misconceptions and conceptual gaps that emerged due to the didactic transposition process. In addition, the analysis was conducted by considering epistemological and didactic aspects to understand the extent to which the shift in knowledge from scholarly knowledge to mathematics taught in class contributed to students' misunderstandings. Data validity was ensured through method triangulation, by comparing the results of observations, interviews, and document analysis to obtain a more comprehensive understanding of the phenomenon being studied.

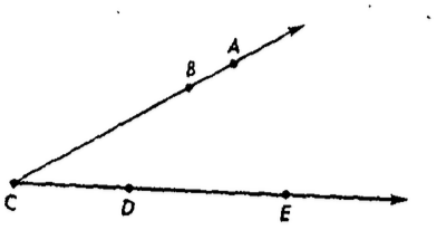
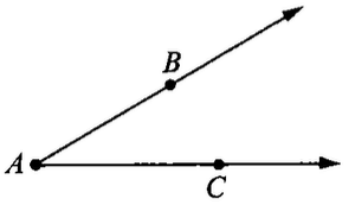
FINDING AND DISCUSSION

In this section, several research findings will be presented. Because of used the perspective of didactic transposition theory, the presentation of the results will follow the stages in didactic transposition, namely the concept of angles and angular measure in scholarly knowledge and the concept of angles and angular measure understood by students (learned knowledge). The goal is to comprehensively understand how the process of transposition of knowledge of the concept of angles and angular measure from scholarly knowledge to learned knowledge.

The Concept of Angle and Angular Measure in Scholarly Knowledge

As explained previously, the concept of angles and angular measure are basic concepts in geometry. Various other concepts in geometry use these concepts. Therefore, in various geometry textbooks that considered as close to scholarly knowledge, the material on angles and angular measure is positioned at the beginning. The concept of angles and angular measure that will be explained in this section is related to their definitions, because from there the concept can be distinguished from other concepts. The summary of the angle definition of the results of the scholarly knowledge analysis can be seen in Table 1, and the angular definition is in Table 2.

Table 1. Summary of Angle Definition in Geometry Textbooks

Analysis Aspects	Summary of Definition
Definition of Angle	An angle is the set of points consisting of the union two rays that have a common endpoint (Lewis, 1968). The common end point is called the vertex of the angle, while the two rays are referred to as the side of the angle. An angle is named by using three capital letters. The letter naming the vertex must always appear as the middle letter. The other two letters are names of two points, one from each of the sides. Thus, in the figure below the angle may be named either angle ACE, written as $\angle ACE$; or $\angle ECA$; or $\angle BCE$; or any one of number of other ways wherein C is always the middle letter.  Figure 2. Illustration of angle's definition (Lewis, 1968) An angle is figure which is the union of two rays which have the same end point, but do not lie on the same line (Moise, 1990). If the angle is the union of $\overrightarrow{AB}$ and $\overrightarrow{AC}$, then these rays are called the sides of the angle, the point A is called the vertex, and the angle itself is denoted by the symbol $\angle BAC$.  **Figure 3**. Illustration of angle's definition (Moise, 1990) An angle is the union of two rays that share a common endpoint (Alexander & Koeberlein, 2020). In figure below, $\overrightarrow{BA}$ and $\overrightarrow{BC}$ have the common endpoint B. This angle represented by $\angle ABC$ or $\angle CBA$. The rays $\overrightarrow{BA}$ and $\overrightarrow{BC}$ are known as the sides of the angle. B, the common endpoint of these rays, is known as the vertex of the angle. When three letters are used to name an angle, the vertex is always named in the middle. Recall that a single letter or numeral may be used to name the angle. The angle in Figure below may be described as $\angle B$ (the vertex of the angle) or $\angle 1$. In set notation, we see that $\angle B = \overrightarrow{BA} \cup \overrightarrow{BC}$.

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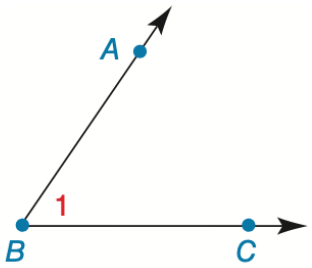
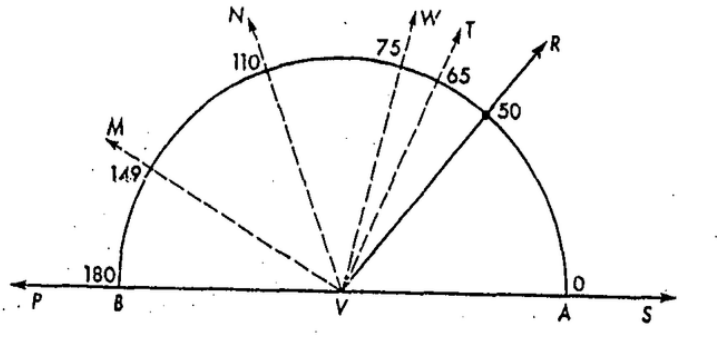


Figure 4. Illustration of angle's definition (Alexander & Koeberlein, 2020)

Table 2. Summary of Angular Measure Definition in Geometry Textbooks

Analysis Aspects	Summary of Definition
Definition of Angular Measure	When placing the vertex of an angle at the point V and one of the sides along the ray VA, the other side of the angle will intersect the arc at some point. The coordinate of this point is called the measure of the angle (Lewis, 1968). In figure below, the measure of $\angle RVS$ is 50. With symbols, this is expressed as $m\angle RVS = 50$. The measure of an angle is merely the coordinate of the point on the arc. As such it is a number and no more.  **Figure 5.** Illustration of Angular Measure (Lewis, 1968) Angular measure is going to be a function m, defined for angles, with real numbers as values of the function (Moise, 1990). Let $\mathcal{A}$ be the set of all angles, $m: \mathcal{A} \rightarrow \mathbb{R}$ is a function of the angles into real numbers. in the usual functional notation, we would write $m(\angle ABC)$ to denote the measure of $\angle ABC$, but since no confusion with multiplication could possibly occur, we omit the parentheses and write merely $m\angle ABC$. The measure of an angle is a unique positive number (Alexander & Koeberlein, 2020). In the explanation, the authors denoted the measure of an angle use m, for the example $m\angle PQR$.

From Table 1 and Table 2, it is clear how the definition of angle and angular measure differs. An angle is a combination of two rays that have the same starting point. This means that when an angle is mentioned, it refers to the set of points that meet the two rays with the same starting point, not a quantity expressed in a positive number. In other words, it can be said that the definition of an angle emphasizes a geometric object formed from the relationship of two rays without considering their size. Unlike angles, the measure of an angle refers to something in the form of a number that represents the shortest rotating path of two rays that have the same starting point. Therefore, in writing, a distinction is made between angles and angular measure, namely for angle measures there is an additional letter m which refers to measure.

The Concept of Angle and Angular Measure Understood by Students (Learned Knowledge)

At the beginning of a plane geometry lecture, the lecturer gave a picture and two simple questions, as seen in Figure 2, to the first-year' students. The lecturer wanted to comprehend how the students understand the concept of angles and angular measures that were understood from the mathematics learning at the previous level. The two simple questions were designed to see how students defined angles and angular measure and their differences. The students' responses to these questions were an early indicator of whether their understanding was in line with scholarly knowledge or not.

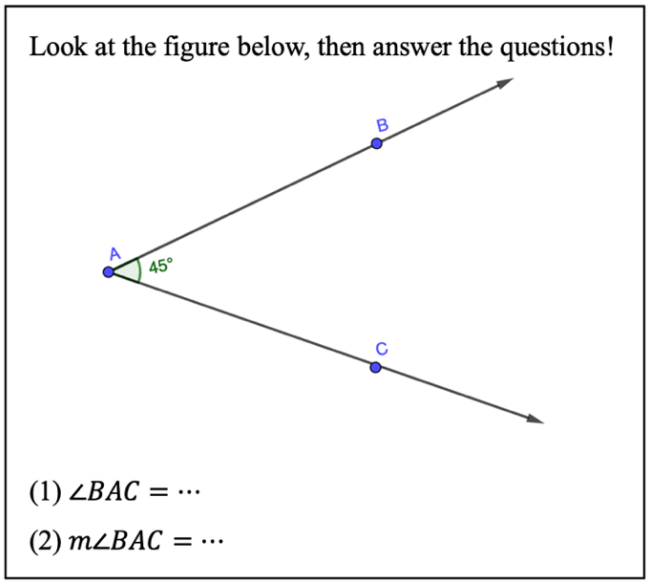


Figure 6. Test Questions

Through the expository process, various interpretations of students regarding the question could be observed. For the first question, all students in the class (N=32) agreed that $\angle BAC = 45^0$. When asked for the reason, one student answered that it can be seen in the picture that the angle BAC is 45. This was confirmed by other students who were seen nodding when their friends answered like that.

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R : Why $\angle BAC = 45^0$?

P1: The angle in the picture is 45, Sir.

R : So, what is an angle?

P1: That's it, Sir (pointing the interior of $\angle BAC$)

R: Researcher; P1: Participant 1

One of the concerns of the researcher is the terminology used, namely "angle." From the interview excerpts and the responses of several other students, it could be seen that the answer given was "the angle is 45.

For question number 2, when asked the answer to $m\angle BAC$, only a few students answered $m\angle BAC = 45^0$. The rest, they did not answer. To confirm it, the researcher asked the reasons from each group. For the first group that answered $m\angle BAC = 45^0$, one of them gave the reason that what was asked was the same as before, namely the angle is 45.

R : What is the answer to this? (the researcher points to question number 2)

P2: 45, Sir.

R : Then, what is the difference with the first question?

P2: (silent, not giving a reason).

Several other students who had an answer of 45 were also not to answer when asked what the difference was between questions 1 and 2. From the conversation, it was apparent that students did not yet fully understand the difference between angles and angular measure.

As for the second group that did not answer question number 2, the researcher tried to confirm.

R : What is the answer to number 2?

P3: I don't know, sir, I'm confused

R : Why are you confused?

P3: There's an m in it, sir.

R : Have you ever seen a spelling using the letter m like that before?

P3: in the books, usually there is no m.

The same thing was also expressed by several other students that they had never seen m before, so they did not understand what the question meant.

Gap Analysis between Scholarly Knowledge and Students' Learned Knowledge

From the description of the two sub-chapters above, it has been presented how the concept of angle and angular measure according to scholarly knowledge and learned knowledge. The first thing that will be discussed is the concept of angle. The angle understood by students with scholarly knowledge is two different things. Referring to scholarly knowledge, an angle is a combination of two rays with the same starting

point (Lewis, 1968; Moise, 1990), meaning that it is more about a set of points. Meanwhile, what students understand is that an angle is a quantity expressed in numbers. From this, it can be understood that students' understanding of angles is a quantity expressed in numbers, not as a combination of two rays that have the same starting point as mentioned in the geometry textbooks explained above. This means that the term angle used refers to the size of the angle, not to its geometric object. This phenomenon shows that there has been a change in the understanding and meaning of a concept. This is not surprising when examined further, for example in junior high school books, the focus of learning angles so far has indeed been more on measuring and calculating angle measurements, while the conceptual aspect of angles as geometric objects is less emphasized.

For the second thing, regarding the size of the angle. Scholarly knowledge stated that the size of the angle is a quantity and is symbolized by m, for example $m\angle ABC$ to indicate the size of the angle ABC (Lewis, 1968; Moise, 1990). Some of the students did not understand the meaning of the letter m because they had never seen it in previous learning levels. Some others, they knew that the use of m was specifically to indicate the size of the angle. However, they could not distinguish it from the concept of angle and tended to equate them. This indicates that their understanding is not comprehensive about the two things.

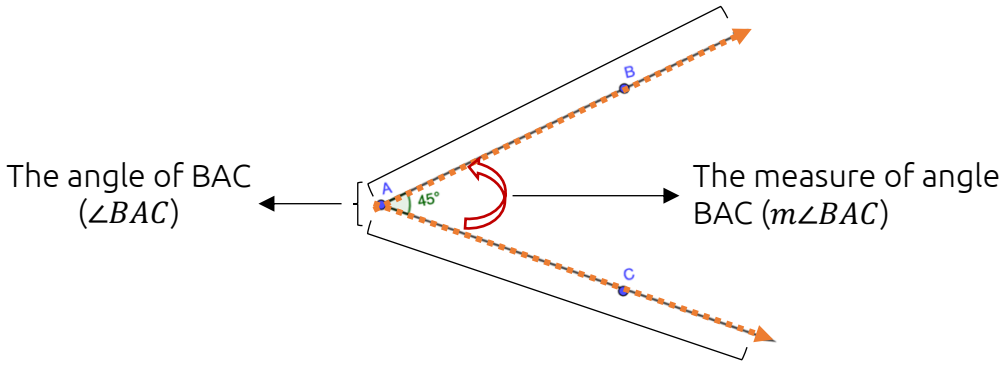

Figure 7. Illustration of the difference between angle and angular measure

From the answers that have been presented for the two questions above, it can be seen that there is an error in students' understanding of the concept of angles and angular measure. This error shows that students do not fully understand the difference between angles as geometric objects and angular measure as quantities that measure the size of angles (See Figure 3 for the difference). In some answers, students tend to equate angles with angular measure, which indicates that their understanding is not in accordance with the formal definition in scholarly knowledge. In other words, it can be said that there is a zone of difference between students' concept images and concept definitions (Vinner, 1983). This error can be caused by the didactic transposition process that does not fully clarify the difference between the two concepts in previous learning (Chevallard, 1989). Jamilah et al.

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(2020) found that an effective didactic translation process will influence the provision of accurate mathematical concepts and the creation of suitable learning environments. In addition, the representation used in textbooks or teaching methods in schools may emphasize more on the aspect of angle measurement without explicitly teaching that the angle itself is a combination of two rays with the same starting point. As a result, when students are faced with conceptual questions, they have difficulty in providing an appropriate definition. This phenomenon shows that there is a shift in meaning in students' understanding due to the didactic transposition they experienced throughout their previous education. Therefore, without any explicitness and clarification in teaching, students can continue to maintain meanings that are not in accordance with formal mathematical definitions (Vinner, 1991). This phenomenon leads to the possibility of limitations in the way mathematical concepts were conveyed at the previous level, where students were not introduced to various forms of representation of the concept of angles and angle measurements. As a result, the variation in the presentation of questions with different notations makes them feel unfamiliar and have difficulty interpreting them, leading to confusion and misconceptions in problem-solving. To address this, teachers need to refer to scholarly knowledge as a reference in designing the mathematical content that will be taught (Herizal, 2023).

CONCLUSIONS AND RECOMMENDATIONS

Didactic transposition is a transposition process of knowledge from knowledge that is reconstructed into knowledge that is organized and taught in the classroom. The process is important to make sure that there are no gaps and misconceptions between the knowledge learned by students and scholarly knowledge. The results of the study show that students' understanding of the concept of angles and angle measurements is greatly influenced by the didactic transposition process in learning. The shift in knowledge that occurs often causes students to have difficulty in distinguishing between angles and angle measurements, even considering both as the same concept. In addition, poor transposition can lead to misconceptions, variations in meaning, and limited knowledge of the concept. Therefore, a more systematic didactic approach is needed to bridge the gap between scientific knowledge of mathematics and students' understanding. The results of this study highlight the importance of alignment between the curriculum, teaching materials, and teaching strategies to be more in line with the structure of academic knowledge. Thus, efforts to improve the didactic transposition process are expected to improve the quality of geometry learning, especially in understanding the concept of angles and angle measurements in more depth.

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