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High impact on students' understanding of atomics radius on crystals geometry concept through implementation of JITT with 3D animation

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Abstract: This study was conducted to analyze the students 'initial and final understanding after the application of JITT with 3D animation, to identify students' responses and arguments, and to determine the impact of using JITT with 3D animation. This research involved 43 students of the 6th semester of the 2019-2020 academic year of the Physics Education study program of the Universitas PGRI Kanjuruhan Malang who took solid state physics course. Students' initial and final understanding was analyzed through responses and arguments presented during the pretest, while the impact of JITT application with 3D animation was analyzed based on the results of the pretest and posttest as well as student responses during the learning process expressed through short interviews and discussions. The qualitative and quantitative data generated from the mixed-method approach were analyzed simultaneously. The results show that the students understand that the atomic radius for all the different crystal lattices is the same, namely **a**/2. This was awakened by an early understanding of the general definition of the radius. However, after following the JITT stages with 3D animation, their understanding changed that the atomic radius of each crystal lattice is different in length. In addition, the results of statistical analysis showed that there was a very significant increase in the students' mastery of concepts from an average of 26.9 to 96.7. Meanwhile, the N-gain value is very high, namely 0.96 in the very effective category, which illustrates that JITT with 3D animation has had a high impact on students' understanding of atomic radius in the concept of crystal geometry.

Keywords:

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Introduction

One of the important things that must be considered by an educator is knowing the students' initial understanding (Jufriadi et al., 2021). Many studies to find out students' understanding and find the best strategy or model to teach the concept of crystal geometry have been conducted. However, the results showed that students had a low understanding of the concepts of crystal lattice and crystal symmetry, covalent bonds, metallic and ionic bonds, non-covalent bonds, molecular bonds, and crystal structures (Brock & Lingafelter, 1980; Gentry et al., 2018; Jones, 2018; Kelly et al., 2010; Steve Krause & Waters, 2012; Milenković et al., 2016; Politzer & Murray, 2017). These concepts are abstract concepts because they relate to very small particles. This causes many interpretations and misunderstandings from students (Podolefsky & Finkelstein, 2007; Pospiech, 2000; Reiner et al.,

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2000). In understanding these abstract concepts, students usually tend to equate them with the properties and characteristics of matter that are familiar in everyday life.

Similar to the concept of crystal geometry about atomic radius, the number of atoms per unit cell and atomic packing fraction are abstract concepts and are at micro size, so that many students have difficulty understanding these concepts correctly. In fact, this understanding will affect students' understanding of the crystal concept as a whole because it will affect the understanding of other related concepts (Jufriadi & Andinisari, 2020). Students' initial understanding that has been formed tends to influence students to understand related concepts or new concepts being learned. This suggests that students' initial understanding and preparation of effective learning designs should be the focus of a teacher to reduce obstacles in the learning process (Hammer, 2000; Rimoldini & Singh, 2005). The designed learning design must be able to improve and strengthen students' understanding or be able to be a liaison between students' initial concepts and correct concepts scientifically.

Studies to explore students' conceptual understanding continue to be carried out by analyzing student responses to multiple choice questions, short interviews, open-ended questions and discussions (Stephen Krause et al., 2003; Prodjosantoso et al., 2019). In addition, the development of learning strategies and models continues to improve students' understanding of weak concepts, including guided discovery models, self-explanation strategies, and the use of plan-views in learning (Cushman & Linford, 2015; Parno, 2015). In line with advances in science and technology, especially in the field of information technology, this development has had a positive impact on the learning process. The integration of information technology in the learning process produces a learning model that combines online and face-to-face learning, known as hybrid or blended learning. Research shows that the hybrid or blended learning model will make it easier for students to build thinking in building a correct and solid concept (Dziuban et al., 2018), stimulate students to actively discuss and share knowledge, improve higher-level thinking skills (Kim & Ketenci, 2019), and provide a higher quality learning experience (Littenberg-Tobias & Reich, 2020). One of the hybrid learning models is Just In Time Teaching (JITT), which is a learning model that emphasizes the preparation of active learning outside the classroom based on information technology (Huan & Chen, 2016; Mangum et al., 2017). Previous research has shown that JITT can improve students' mastery of concepts better when compared to traditional models (Ayu et al., 2019; Barikhlana et al., 2019; Jufriadi & Andinisari, 2020).

In addition, 3D animation is widely used in learning to help students understand complex phenomena easily and comfortably, visualize abstract phenomena, and improve the quality of learning (Bakri et al., 2019; Bhatti et al., 2017; Elmunsyah et al., 2019). Several previous studies have also shown that the use of 3D animation can increase students' motivation and mastery of concepts (AbdelAziz et al., 2020; Hiranyachattada & Kusirirat, 2020; Ho et al., 2019).

Although research on the application of JITT and 3D animation in learning has been widely conducted, this research has not yet had a maximum effect on students' mastery of concepts. Most research on the application of 3D has not paid attention to students' initial understanding of the concepts to be conveyed. By applying the JITT model with 3D animation, students' initial understanding will be explored first at the warming up stage, so that the use of 3D animation can have a high impact on students' conceptual understanding. This study aims to analyze students 'initial understanding of the atomic radius in the concept of crystal geometry, the arguments presented by students during the learning process, and students' mastery of concepts after the learning process, as well as to analyze the impact of using integrated 3D animation with the JITT model.

Method

The research was conducted by applying the JITT with 3D Animation model with a mixed method approach and a single-phase embedded-experiment design (Edmonds & Kennedy, 2016) as shown in Figure 1.

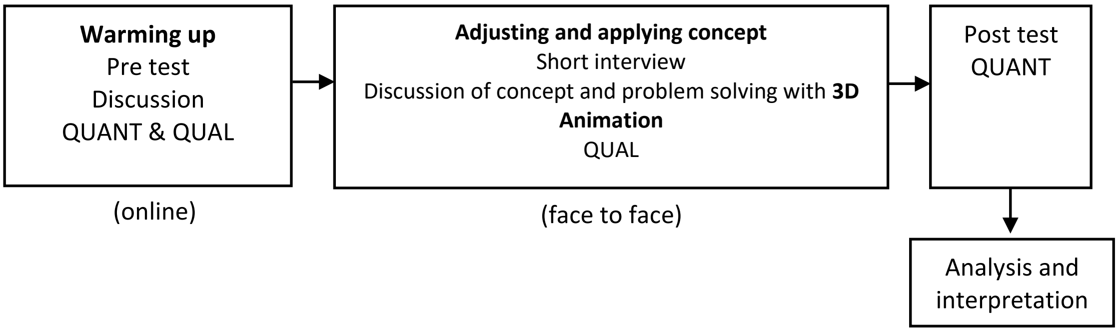

Figure 1. JITT with 3D Animation using Mix Method Approaches: Embedded-Experiment

The data that has been analyzed in the study consists of quantitative data and qualitative data. Quantitative data is data that has been obtained from the results of the pretest and posttest with the same test instrument, while qualitative data is generated from the results of discussions and interviews at the warm-up stage and the learning process in class.

The research subjects were 43 students of the 6th semester of the 2019-2020 academic year of the Physics Education study program, Universitas Kanjuruhan Malang. The research instrument used was 9 multiple choice items, with the indicators for each question as stated in Table 1.

Table 1. Test Instrument Indicator

Test Indicator	Test number
Describe of atomic radius	1, 4, 8
Describe of number of atoms per unit cell	2, 5, 7
Describe of atomic packing fraction	3, 6, 9

The concepts of crystal geometry that have been discussed are atomic radius, number of atoms per unit cell, and atomic packing fraction. However, in this article, researchers only discuss in depth the first indicator, namely the 'Describe of atomic radius'. This is because based on the results of the analysis of student answers through interviews and tests, the impact of JITT with 3D animation on this indicator is very high compared to the other 2 instrument indicators. Learning JITT with 3D Animation has been started by giving pretest questions and discussion about concepts online. After online learning, it is continued with face-to-face learning in class by discussing material with 3D animation and discussing various problem solutions. After the learning process is complete, it is followed by a direct posttest.

Quantitative data analysis was carried out by calculating the effect size and normalized gain (Bao, 2006). Meanwhile, the qualitative data were analyzed based on the reasons put forward by the students in the pretest and posttest responses. Data analysis was carried out to determine students' understanding of concepts and their improvement, as well as to find out students' arguments which were used as the basis for building their understanding.

Results and Discussion

Students' initial understanding of atomic radius

The problems that have been presented to reveal students' understanding of atomic radius in the concept of crystal geometry are shown in Figure 1. The concept of atomic radius is represented in three questions with different contexts, but uses the same principle in solid states physics.

Based on the pretest answers that have been analyzed, the arguments of students' answers and the results of discussions, also short interviews with students, it can be concluded that they have understood the general definition of atomic radius, namely the distance between the center point to the atomic surface point. Students' initial understanding of the general definition is revealed in the early class learning session. However, the students' initial understanding could only be used to calculate the atomic radius of simple cubic (SC) and could not be used to solve problems, especially the application for atomic body centered cubic (BCC) and face centered cubic (FCC). Therefore, in general they are not able to answer correctly to the questions that have been presented. This is shown from the distribution of student answers in Table 1.

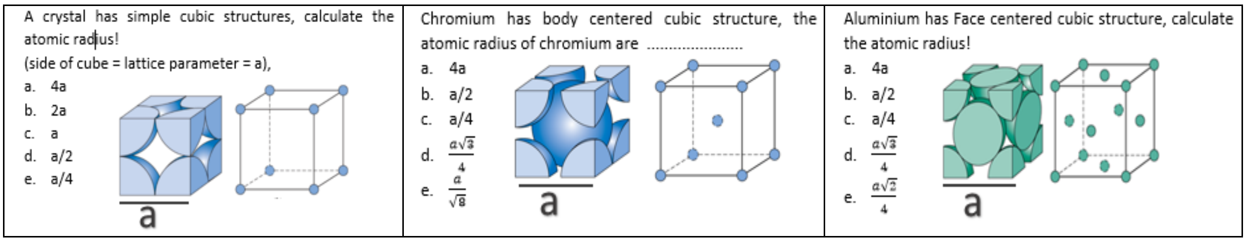

Figure 2. Questions to find out students' understanding of atomic radius

Table 1. Distribution of student pretest answers for the concept of atomic radius

Number of Question	Student' Answer (%)				
	a	b	c	d	e
1	4,7	4,7	9,3	81*	0
4	7	77	5	7*	5
8	12	77	5	7	0*

* Correct answer

In general, students have answered that the atomic radius of all cube crystals is the length of the side of the cube divided by two (a/2). The correct answer to question number 1 is 81%, question number 4 is 77%, and question number 8 is 77%, on the grounds that the radius is half the circle and the distance from the center point to the sphere.

This initial understanding was also shown by students during short interviews that were conducted at the beginning of face-to-face learning, such as the following short interview scripts between researchers and students:

Researcher : *What do you know about the atomic radius?*
Student : *The atomic radius is the same as the radius of a sphere or circle, right? (student asks back)*
Researcher : *How can that be?*
Student : *The atom is in the form of a sphere or circle ... so if the atom is the same, it means that the atomic radius can be interpreted as this ... (while making a circle and drawing a line from the center to the surface of the circle), the distance from this center point to the surface outermost circle.*
Researcher : *Then ... what about the answer to the problem about atomic radius?*
Student : *mmmm ... the side of the cube is **a**, and it is also equal to twice the radius (students describe simple cubic). So, the radius is **a** divided by two.*

Based on the responses to the written answers and the interviews, it is very clear that students have used previous knowledge or experience about the concept of fingers in general that they get from their learning environment. This shows that the knowledge or information possessed by students before learning affects their understanding of the next concept. Students already have initial concepts that are used to interpret and understand the problems at hand (Eshach et al., 2018; Fotou & Abrahams, 2016; Hammer, 2000), but this understanding is used directly to solve problems by students without paying attention to geometric aspects of the crystal lattice, so they believed that the length of the atomic radius of several crystal lattices was the same, namely **a**/2. Student behavior reflects "recursive plug and chug" in epistemic games (Tuminaro & Redish, 2007).

Pretest and discussion in the early stages of JITT learning have provided information about students' initial understanding and should be emphasized during learning. In general, students have believed that all crystals with various structures have the same atomic radius length, namely **a**/2. The findings about students' initial understanding at the warming up stage are in accordance with the findings of other researchers, namely the warming up at JITT can provide information about students' initial understanding and abilities (Ayu et al., 2019; Barikhlana et al., 2019; Jufriadi & Andinisari, 2020).

Students' final understanding of atomic radius

Data on the distribution of students' posttest answers in Table 2 shows that in general students have been able to understand the concept of atomic radius in crystal geometry. This is indicated by the very high percentage of students' correct answer distribution, which is 100% for question number 1, 93% for question number 4 and 97.7% for question number 8.

Table 2. Distribution of student posttest answers

Number of Question	Student Answer (%)				
	a	b	c	d	e
1	0	0	0	100*	0
4	0	0	2,33	93*	4,65
8	0	0	0	2,33	97,7*

* Correct answer

The answers and arguments that have been put forward by the students show that they have correctly mastered the concept of atomic radius in crystal geometry. This correct understanding has been supported by student responses in short discussions that have been carried out during the learning process, as in the following discussion script:

Researcher : *Do you notice the difference the following crystal lattice? (researcher shows 3D animation of cube crystal lattice, as in Figure 2)*
Student 1 : *The number of atoms ...*
Student 2 : *The corner atoms on the SC coincide while those on the BCC do not ...*
Researcher : *Ok ... that means for BCC, where are the coincide atoms?*
Student 3 : *On the diagonal of space... that means the atomic radius between SC and BCC is different. Is that right, Sir? (student asks)*
Researcher : *What do you think?*
Other student: *Yes, it is different, Sir... mmm so the FCC is also different because the atoms are coincided together on the diagonal side. Hehehe...*
Researcher : *Why are you laughing?*
Student 3 : *Our answer on the last pretest were wrong, Sir.*
Other student: *yes...shouldn't be all **a**/2...*

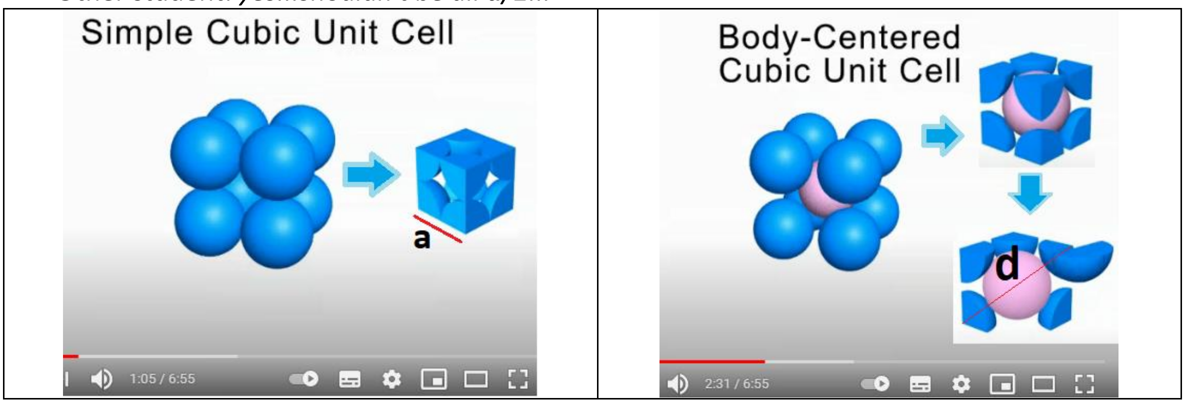

Figure 2. Crystal lattice 3D animation

From the class discussion that has been conducted when the researcher displays the 3D animation of the crystal lattice, it is very clear that there has been a change in students' understanding, especially regarding their initial understanding that "all atomic radius in various crystal lattices are the same, namely **a**/2" becomes a correct new understanding that "the atomic radius of a crystal lattice with different structures has a different magnitude." In this learning process, the 3D animated display has been able to provide a clear visualization of the structure of the atoms in the SC, BCC, and

FCC. The SC structure shows atoms coincide on the side of the cube, the BCC structure shows atoms coincide on the diagonal of space, and the FCC atomic structure shows atoms coincide on the side diagonal. Based on the 3D animation visualization, students can conclude that SC, BCC, and FCC have different atomic radius.

The use of 3D animation has made it easier for students to understand the concept of crystal geometry. These results are in line with previous research which showed that the use of 3D animation has been able to improve students' conceptual understanding, as well as support the learning process and student independence (Elmunsyah et al., 2019; Hiranyachattada & Kusirirat, 2020). However, the use of JITT, especially the warming up stage in this study, has been able to maximize the use of 3D animation so that it provides a very high understanding for students. The warming up stage has provided information about the weakness of student understanding which has been used as a basis for using 3D animation on material that has not been mastered by students properly.

The application of JITT with 3D animation has had a high impact on students' understanding of the concept of crystal geometry. This has been concluded based on the statistics shown in table 3, which shows an increase in the average mastery of concepts before the implementation of JITT with 3D animation and after, namely from an average of 26.9 to 96.7.

Table 3. Descriptive statistics of students' mastery of atomic radius concept based on pretest and posttest

Statistics	Pretest	Posttest
N	43	43
Mean	26,9	96,7
Minimum	0	30
Maximum	65	100
Standard Deviation	15,7	12,8

Based on the paired t-test analysis, a significance value of 0.00, or less than 0.05, was obtained. Statistically, this shows that there is a significant difference in students' mastery of concepts before and after the implementation of JITT with 3D animation. In addition, the N-gain result has been calculated with a high score of 0.96 which is categorized as very effective (Hake, 1998). Therefore, in general, the application of JITT with 3D animation has a high impact on increasing students' understanding of the crystal geometry concept. This is in accordance with other research which shows that JITT is able to have a positive effect on concept mastery and achievement (Jufriadi & Andinisari, 2020). However, the use of JITT with 3D animation for other physics concepts still needs to be researched and studied, especially for basic concepts that do not require analogies.

Conclusion

In general, students already have initial knowledge about the definition of atomic radius. This knowledge has been used directly to give the initial conclusion that all crystal lattices have the same atomic radius **a**/2. This initial knowledge of students can be revealed at the warming up stage of JITT learning. Concept change occurs when learning uses 3D animation. In this learning, students are able to conclude that atomic radius in crystals with different structures have different radius lengths. As a result, the JITT model with 3D animation has had a high impact on students' understanding of atomic radius in the concept of crystal geometry.

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