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Nature of Science v.s Direct Instruction Models in Achieving Senior High School Students' Critical Thinking and Their Attitudes in Learning Physics

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Abstract. Learning physics in senior high school tends to apply direct instruction (DI), not yet concerned with the nature of science (NOS) model. This study aimed to examine the comparative advantage between the NOS and DI models in achieving students' critical thinking and attitudes. The study utilized the post test only control group design. The study population was 5 classes or 137 students of class XI MIPA senior high school 1 Busungbiu Buleleng. Random assignment techniques are used to determine two classes or 58 students (42.3% of population) as sample. The experimental group was MIPA-1 class or 29 students and the control group was MIPA-2 class or 29 students. Critical thinking data were collected by 12 essays and student attitudes with a questionnaire consisting of 40 items: 20 items measuring social attitudes and another 20 items measuring spiritual attitudes. Data were analyzed by one way MANOVA. The results showed that the NOS model was significantly superior to the DI model in achieving critical thinking and student attitudes in learning physics in Senior High School. The average value obtained by the NOS group was M = 29.66 and the DI group was M = 24.25 on a 100 point scale, which means they fall in the very low category. This is a challenge for the next especially for the NOS application in learning physics.

INTRODUCTION

Today, the world of education has been in the 21st century known as the age of knowledge. Education in the age of knowledge faces very severe challenges, including having to be able to facilitate students to build competencies that are in line with what is needed in this century. This is indeed in line with the development of the 21st century education direction, which has shifted from a traditional content-based approach to a competency-based approach that is more comprehensive and cross-cultural [1]. In Indonesia, competency-based curriculum has been initiated since 2004. Universally, the curriculum is defined not only focusing on the academic knowledge contained in various subjects, but also attitudes, skills, behaviors and values [2]. In addition, education in the present era must adapt to the four pillars of education proclaimed by UNESCO [3], namely learning to know, learning to do, learning to life together, and learning to be. Related to the 'learning to be' pillar, there is recommend that school curricula be balanced, which not only takes into account intellectual cognitive competence, but also spiritual, moral, social skills and values [4]. Therefore, the latest development of competency-based curriculum in Indonesia has been refined to become the 2013 Curriculum (K-13), which is operationally directed to the achievement of 4 core competencies, namely spiritual competence, social

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competence, cognitive competence, and psychomotor competence.

The facts above show that student competencies in learning in schools need to be improved. One innovative way that educational praxis should intensify the application of the student centered learning (SCL) approach. This approach puts students as the center of learning activities [7]. The model becomes a vehicle for students to develop time management skills, communication, critical thinking and problem-solving skills [8]. Especially in an effort to improve students' critical thinking, previous research has examined the effect of SCL models, namely problem-based learning (PBL) models on critical thinking of high school students [9]. They found that PBL was effective in increasing students' critical thinking in physics learning. Other studies have also compared the effect of the ORIPA model as a SCL and PBL model towards critical thinking students of physics teacher candidates [10]. They show that the ORIPA model is superior to the PBL model. The SCL approach focuses on autonomous student enrolment that is capable of developing critical thniking and attitude [8]. The SCL approach is also explicit and implicit included in the nature of science (NOS) learning model.

Based on the problems background above, this study focuses on answering the question: "Is the application of NOS models superior to direct instruction (DI) models in achieving critical thinking, social attitudes, and spiritual attitudes of students in learning physics in senior high school?"

Theoretical Framework

Nature of Science (NOS) Learning

Physics learning in order to achieve critical thinking skills, social attitudes, and spiritual attitudes cannot be separated from the nature of physics as a process, product, and attitude [11]. Critical thinking is an implication of the nature of physics as a product that must be supported by a good scientific attitude in undergoing the learning process, while social attitudes and spiritual attitudes are not only the effects of learning accompaniment, but also an implication of the nature of physics as an attitude [13]. The NOS model is an important part in the development of a physics curriculum. The results of the study indicate that the NOS curriculum which is based on an interdisciplinary approach, aims to attract students' attention and examine background knowledge, as well as accommodate changes in positive attitudes and improve student understanding [13]. They advocate alternative ways, namely with the help of presenting information and with related questions and explanations, open questions and activities that connect various fields of scientific studies related to each other. This is very important to be implemented in physics learning so that the physics learning process becomes more effective, so as to obtain optimal products. NOS is an innovative student-centered learning that is effective in improving learning processes and products [14].

Based on the criteria of physics learning, it can be understood that physics learning will not be optimal if it only tolerates the nature of physics as a product. In other words, physics learning is not enough anymore if done with direct instruction (DI), but must use student centered learning (SCL). One of them is nature of science (NOS) learning. In physics content, NOS can be arranged in four main dimensions [15], namely: (i) physics epistemology (the difference between observation and inference, the role of law and theory, creativity, the nature of tentative truth, empirical basis , modeling), (ii) the relationship between physics and technology (the difference between physics and technology, mutual influence, and the idea of techno science), (iii) internal sociology of physics (social construction of scientific knowledge, interest and value of scientists, professional communication of scientific knowledge, and individual influence), (iv) sociology of external physics (the influence of physics on society and vice versa, social problems and decisions, social responsibility, economic pressure, and lobbying).

Direct Instruction

The term direct instruction (DI) is affiliated with instructional approaches and curriculum material developed by Sigmun Friud and Carl Rogers in the late 1960s [17]. Learning is done specifically and explicitly, based on the behaviorist classical stimulus / response / conditioning model developed by B. F. Skinner. The learning program provides teachers and schools with a linearly programmed learning model. The teacher follows step by step, a lesson-by-lesson approach that follows a sequence of predetermined skills and is then given to students. The approach that is determined to teach is fast and linear which aims to maximize timeliness

in carrying out tasks, and positively strengthen student behavior. The teacher provides rigorous training by following the teacher's guidebook. The teacher focuses more on the effort to present curriculum material. The presentation of the material is followed by giving assignments, giving tests, and conducting assessments that are in line with the learning objectives that have been set. Evaluation results are followed by feedback to change behavior, ability grouping, and emphasis on academic skills. Operationally, the DI model is applied with the following steps: motivating students, delivering lesson material, forming groups of students, students learning in groups, students reporting the results of the discussion, teachers evaluating student reports.

Critical thinking

Critical thinking is "reasonable reflective thinking that focuses on deciding what to believe or do [18]. In deciding what to believe and do, a person is helped by a set of critical thinking skills. When students think critically, they are encouraged to think for themselves, formulate hypotheses, analyze and synthesize events, to go further by developing new hypotheses and test them based on empirical facts [5]. In other words, students think critically look like scientists who are doing research, formulating question, reject information as it is, active, analytic and synthesis thinking, evaluate information and explain on the right basis, treat an open mind and be aware of the thinking process. Each student must have effective critical thinking skills, and they must not accept what said the teacher Therefore, teachers must critically provide learning facilities that can encourage students to think critically. One way that can facilitate students developing critical thinking is the NOS learning model.

Social attitude

Social attitudes are part of interpersonal intelligence. Social attitudes include 4 (four) main things [19, 20, 21], namely (1) the attitude of organizing groups, (2) the attitude of negotiating solutions, (3) the attitude of maintaining personal relationships, and (4) attitude of doing social analysis.

Spiritual attitude

A struggle for the development of ideas, [22] describes Plato's belief that the main role of education is to challenge students to increase spiritual awareness. He stated that

> *Education is the maximizing of the students' acquisition of the cultural artefacts generated by other human beings, so that they become what may be, inadequately, called cognitive tools. The more of these we have available for making sense of the world and experience, the better chance we have of appreciating those visions of human experience we collectively call Spirituality* [22].

Egan's view suggests that the world with its contents is not enough to be seen only with cognitive tools, but must involve other abilities, namely spiritual attitudes. There were identified 8 dimensions of spiritual attitudes, consisting of 1) Meaningfulness, 2) Trust, 3) Acceptance, 4) Awareness in the Present, 5) Caring for Others, 6) Connectedness with nature, 7) Transcendent experiences, 8) Spiritual Activities [23]. Egan proposes 5 (five) components for developing students' spiritual attitudes, namely (1) encouraging students to improve their understanding and beliefs about the world and their experiences; (2) introducing them to the way humans fight for life based on intense experience; (3) introducing them to goodness and virtue, such as thoroughness, warning, prudence, and enthusiasm in observing, and delighting in the process of discovery; (4) encouraging them to feel the joy of self-sacrifice for the good of others; and (5) inviting them to understand the findings of various things in the past and how to build them forward [22].

METHOD

This study was a quasi-experiment with non-equivalence post-test only control group design. The population was 5 classes (137 students) of XI MIPA senior high school 1 Busungbiu, Buleleng Regency of Bali. The sample selection used random assignment technique to select 2 classes which were then randomly assigned to class XI MIPA-1 (29 students) as the experimental group and class XI MIPA-2 (29 students) as the control group. The total sample was 58 students or 42.3% of the population. The experimental group studied using the

NOS model, while the control group the DI model.

The treatment in both groups was done by the teacher. Previously the teacher received training before starting to give the treatment. The training lasted four weeks of two hours a week. In the first week, the teacher received a consecutive explanation about the learning of NOS and DI. In the second week, the teacher practiced observing learning plans and implementation, student worksheets, and assessment techniques and learning evaluations of NOS and DI. In the third week, the teacher made a presentation and discussed his understanding with the instructor in conducting NOS learning, and in the last week, the teacher made a presentation and discussed his understanding in doing DI learning. Next the teacher carried out the treatment in both groups of students. Both groups studied physics material on the topics were sound waves and light waves. The treatment was carried out for 5 weeks each for 3 hours face to face. The details of the topic for each face-to-face meeting are presented in Table 1.

Table 1. Allocation of time and topics for each face-to-face meeting

Week	Topic	Time allocation
1	Sound and string properties	3 hours
2	Organ pipe, sound intensity, and sound intensity level	3 hours
3	Fast sound propagation and Doppler effect	3 hours
4	Dispersion, reflection and refraction of light	3 hours
5	Interference, diffraction, and polarization of light	3 hours

The learning steps in the NOS model are theoretically and operationally different from the learning steps in the DI model. The comparison between the NOS model treatment and DI model treatment is presented in Table 2.

Table 2. Description of learning steps and activities in the NOS and DI models

NOS Model		**DI Model**	
Learning Steps	**Learning activities**	**Learning Steps**	**Learning activities**
Determining and formulate problems	Students trace and criticize various sources related to the subject matter	motivating students	The teacher motivates students regarding the subject matter discussed
Discussing the issues under study	Students discuss problems found including those facilitated by the teacher	delivering lesson material	The teacher presents the subject matter followed
Designing laboratory experiments	Students are guided by the teacher to formulate the problem and make a theoretical and empirical solution design	forming groups of students	The teacher instructs students to form groups of 3-5 people and share group assignments
Conducting observational-based research in laboratories	Students conduct an investigation in a laboratory or other place that supports the process of achieving a guide-based solution facilitated by the teacher	students learning in groups	Students work on assignments given by the teacher in each group and formulate the report on the results of the discussion
Studying the historical development of related science	Students present the results of their group discussions in class, and report on the solutions that have been achieved	students reporting the results of the discussion	The teacher appoints the group in turn to report the results of the discussion
Using multiple assessments to assess and evaluating various student activities	Students are assessed by the teacher when conducting discussions, laboratory investigations, and presentations	teachers evaluating student reports	The teacher assesses student discussion reports and gives quizzes

The treatment as in Table 2 was carried out for 5 meetings. At the 6th meeting, the students in both groups were given a critical thinking test in learning physics with a time allocation of 90 minutes. Over the next 30 minutes, the students answered social attitudes and spiritual attitudes.

The critical thinking test was written in an essay test format with each item rubric using a 5 points scale. For example item number 1 critically provides the argument: "Professional divers want to dive in an ocean whose depth is not yet known. Sonar technique is used to measure the depth of the area, which shows the sound results quickly propagating 1200 m/s is received again after ¾ seconds, do you think, whether divers will survive if humans are only allowed to reach the depth of the sea as deep as 400 m before dying to receive excessive hydrostatic pressure?" Based on the trial result 12 items were used in collecting the data. The test blueprint, discrimination index (ID), item difficulty index (IDI), and item-total correlation coefficient (r_{xy}) are presented in Table 3.

The social attitude scale was adapted from conceptions which covered 4 main dimensions [19, 20, 21], namely 1) the attitude of organizing groups, 2) the attitude of negotiating solutions, 3) the attitude of maintaining personal relationships, and 4) attitude in carrying out social analysis. Four dimensions of social attitudes were translated into the 30 items of the social attitude instrument. Each item used a Likert Scale by removing the neutral element, so that the scale was reduced to a 4 points scale. Studying in school has my social impact not to say dirty words, rude and arrogant, is an example of social attitude item number 30 which includes "the attitude of maintaining personal relationships". The results of the trial with 291 subjects showed that the correlation coefficient of the total-item of social attitude questionnaire ranged from 0.36 to 0.60 and the 30 items had a reliability coefficient of 0.91, falling into a very high qualifications.

Spiritual attitude used eight dimensions adapted from subscales and spiritual attitudes and involvement lists (SAIL) items [23], which consists of 1) meaningfulness, 2) trust, 3) acceptance, 4) awareness in the present, 5) caring for others, 6) connectedness with nature, 7) transcendent experiences, 8) spiritual activities. The eight dimensions of spiritual attitudes were differentiated into 30 items. Each item used a Likert Scale by removing the neutral element, so that the scale became a 4 points scale. Studying at school has a spiritual impact on me, I like to meditate or pray, or use the time for other spiritual activities to find inner peace, is questionnaire spiritual attitude item number 29, which is included in the "spiritual activities". The results of trials with 294 subjects showed that the correlation coefficient of the total-item of spiritual attitude questionnaire ranged from 0.30 to 0.61 with 30 item reliability coefficient of 0.84, falling into a high qualification.

This study tested the null hypothesis (Ho): "there is no difference in critical thinking, social attitudes, and spiritual attitudes between students who study with the NOS model and the DI model". To test the hypothesis, the one-way MANOVA was used which was followed by a test of between subject effect and a comparison of the mean scores between the groups. Assumption testing included the testing of the normality of data distribution using Kolmogorov-Smirnov and Shapiro-Wilk statistics, the similarity test of covariance matrix using Box's M test, and the test of similarity of variance between groups using Levene's test. The hypothesis testing used a significance level of 5%.

RESULT AND DISCUSSION

Results of Descriptive analysis

The result of this descriptive analysis showed the effect of nature of science (NOS) learning compared to that of direct instruction (DI) in achieving of 3 dependent variables, namely critical thinking, social attitudes, and spiritual attitudes of the students at senior high school 1 in Busungbiu Buleleng. Comparison of the average score of students for each item test of critical thinking between the experimental groups (students who study with the NOS model) and the control group (students who study with the DI model) is presented in Figure 1.

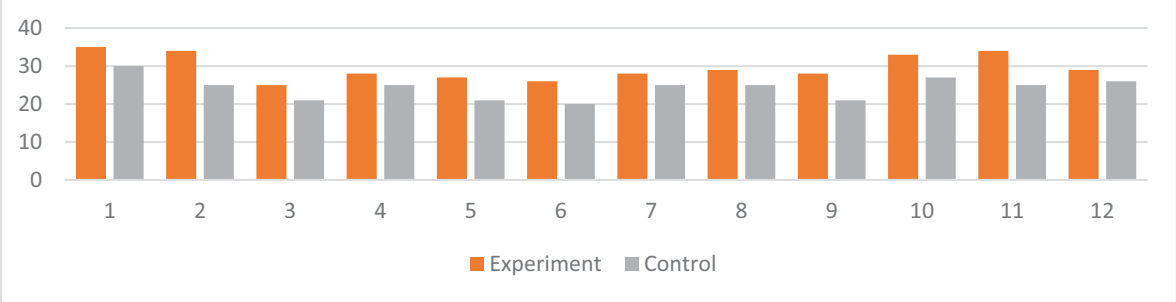

Figure 1. Descriptive comparison of the difference in the average scores of each test item in critical thinking

Based on Figure 1, it appears that critical thinking of students who study with the NOS model is descriptively higher than that of critical thinking students who study with the DI model. Comparison of critical thinking students in each dimension of critical thinking between students who learn with the NOS model and DI model is presented in Figure 2. In Figure 2 also shows that descriptively students who learn with the NOS model show higher performance in each dimension critical thinking compared to those who study with the DI model.

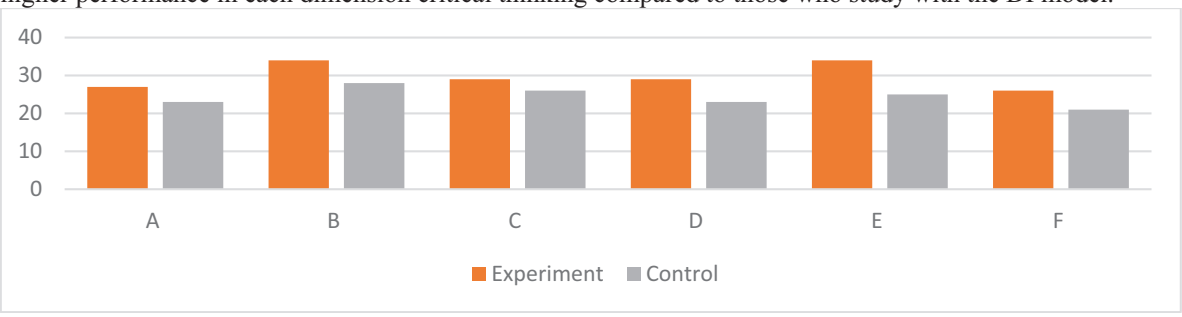

Figure 2. Comparison of the difference in the students' critical thinking in each dimension of critical thinking, A = Formulating a problem, B = Giving argument, C = Analyzing deductively, D = Analyzing inductively, E = Evaluating, F = Making a decision and doing an implementation.

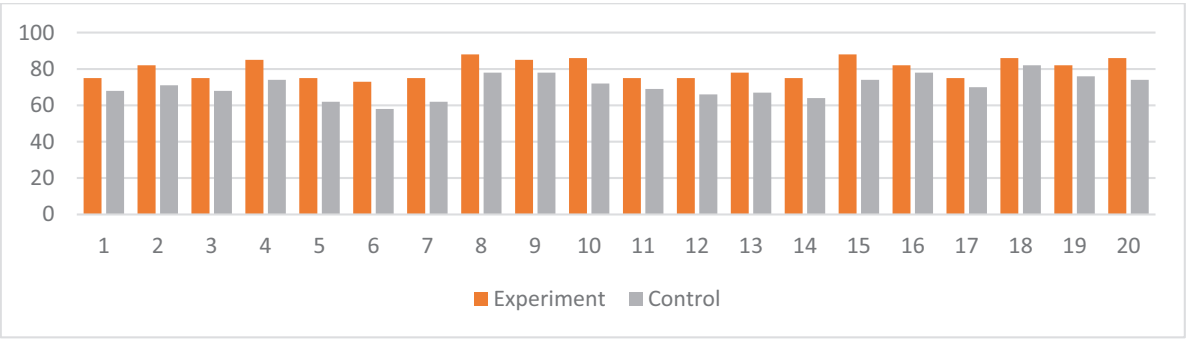

Figure 3. Comparison of the difference in the average scores for each item in the social attitude questionnaire

Figure 3 shows that the social attitudes of students who learn with the NOS model descriptively are higher than those who learn with the DI model. This result is consistently shown in all items of social attitude instruments. Based on Figure 4, it also appears that the students' spiritual attitudes on each item of the spiritual attitudes questionnaire achieved by students who studied with the NOS model were descriptively higher than those achieved by students who studied with the DI model.

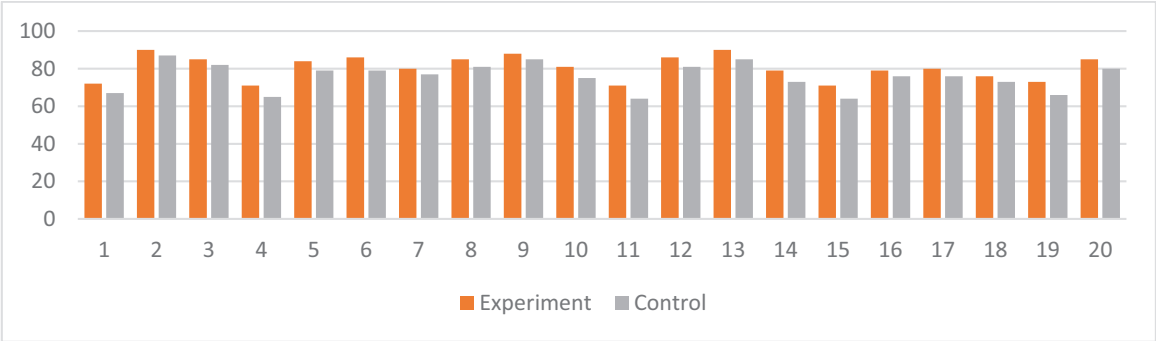

Figure 4. Comparison of the difference in the average score for each item in the spiritual attitude questionnaire

Table 3. Summary of the results of descriptive analysis of critical thinking skills, social attitudes and spiritual attitudes

Dependent variable	MODEL	MEAN	SD	N
Critical thinking	NOS	29.66	5.60	29
	DI	24.25	4.55	29
Social attitude	NOS	80.05	9.19	29
	DI	70.55	7.58	29
Spiritual attitude	NOS	78.95	10.27	29
	DI	71.75	8.03	29

Descriptive analysis results in Table 3 show that the students who learned with the NOS model demonstrated better critical thinking skills, social attitudes, and spiritual attitudes descriptively than the students who learned the DI model.

Test of assumption

Test of assumptions made included the testing the normality of data distribution using Kolmogorov-Smirnov and Shapiro-Wilk statistics, Box's Test of Quality of Covariance Matrices, and Levene's Test of Equality of Error Variances. A summary of the test results is presented in Table 4, Table 5, and Table 6.

Table 4. Summary of the results of the normality test of data distribution of dependent variable

	Kolmogorov-Smirnov			Shapiro-Wilk		
Dependent variables	Statistic	df	Sig.	Statistic	df	Sig.
Critical in NOS	.125	29	.200	.940	29	.103
Social in NOS	.125	29	.200	.960	29	.322
Spiritual in NOS	.092	29	.200	.973	29	.644
Critical in DI	.161	29	.064	.933	29	.066
Social in DI	.110	29	.200	.975	29	.700
Spiritual in DI	.171	29	.129	.840	29	.089

Based on the results of the normality test in Table 5, it appears that the statistical values of Kolmogorov-Smirnov and Shapiro-Wilk on the three dependent variables, both in learning with the NOS and DI models, have a higher level of significance compared to 0.05. So the data of critical thinking skill, social attitude, and spiritual attitude of students were normally distributed.

Tabel 5. Box's test of equality of covariance matrices data of dependent variables

Box's M	7.833
F	1.229
df1	6
df2	22721.208
Sig.	.287

The Box's Test of Equality of Covariance Matrices results as shown in Table 6, that the Box's M statistical value was F = 1.229 with a level of significance of 0.427 which was greater than the 0.05 level of significance. This means that the dependent variable covariance matrices were homogeneous. This test result was an assumption of the Multivariate Analysis of Covariance. As an assumption, Tests of Between-Subjects Effects required Levene's Test of Equality of Error Variances. A summary of the test results is presented in Table 6.

Tabel 6. Levene's test of equality of error variances data of dependent variables

Dependent variables	**F**	**df1**	**df2**	**Sig.**
Critical thinking	1.773	1	56	.188
Social attitude	.377	1	56	.542
Spiritual attitude	3.792	1	56	.057

Table 6 shows that the Levene's statistical values for all dependent variables have a level of significance greater than 0.05. Therefore, the three variances of the dependent variables of the NOS and DI treatment groups are homogeneous.

Hypothesis Testing

The result of analysis shows that the MANOVA assumptions have been fulfilled, Table 7 below presents Multivariate Analysis of Covariance.

Table 7. Multivariate analysis of covariance effects of NOS v.s DI on the dependent variables

Statistic	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Pillai's Trace	.224	5.210	3.000	54.000	**.003**
Wilks' Lambda	.776	5.210	3.000	54.000	.003
Hotelling's Trace	.289	5.210	3.000	54.000	.003
Roy's Largest Root	.289	5.210	3.000	54.000	.003

Based on Table 7, it appears that Pillai's Trace statistic, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root respectively yield F = 5.210 with the level of a significance of 0.003 smaller than sig. = 0.05. Thus, the three dependent variables show a significant difference between NOS and DI treatments. The null hypothesis which states that there is no difference in the variables of critical thinking, social attitudes, and spiritual attitudes between the students studying with the NOS model and those learning with DI model is rejected. In other words, the three dependent variables differ significantly for the students who study with the NOS model and those who studied with DI model. This result provides an indication of the need for Tests of Between-Subjects Effects of each dependent variable, the result of which is presented in Table 8.

Tabel 8. Tests of Between-Subjects Effects of NOS v.s DI on the dependent variables

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	Critical thinking	152.345	1	152.345	5.836	.019
	Social attitude	424.983	1	424.983	5.987	.018
	Spiritual attitude	662.345	1	662.345	7.789	.007
Error	Critical thinking	1461.931	56	26.106		
	Social attitude	3974.897	56	70.980		
	Spiritual attitude	4762.069	56	85.037		

Table 8 shows that separately the three dependent variables differ significantly for the NOS and DI treatment results. Thus, the null hypothesis which states that there is no difference in the variables of critical thinking, social attitudes, and spiritual attitudes between the students studying with the NOS model and those learning with DI model is rejected. In other words, the three dependent variables each differ significantly for the students who studied with the NOS and those who studied with DI models.

Discussion

The results showed that comparatively NOS model was significantly superior compared to DI model in achieving critical thinking, social attitude, and spiritual attitude of the students in learning physics in class XI of Senior High School students in Busungbiu Buleleng on the topics of sound waves and light waves. The difference in effect applied to the three dependent variables - critical thinking, social attitude, and students' spiritual attitude simultaneously, and also to each individually. The findings of this study are consistent with the results of previous studies [16, 16, 27]. The NOS model application in this study used guided inquiry steps. In this context, the result of this study confirms the findings before, that guided inquiry learning models significantly influence students' critical thinking ability in the topics of sound and energy [24]. In the NOS model application, in addition to conducting inquiry, the students also collaboratively conducted research and discussed scientifically using scientific principles, such as scientific attitudes, honesty, cooperation, respect for other people's opinions, ethics, all of which lead to gratitude and admiration toward God is the greatest power that is an inspirational source and the cause of everything. In this context, of course the NOS model application can provide an accompanying impact in the form of social attitude and good spiritual attitude. Collaborative processes do not only benefit students 'academic performance, but also increase students' self-efficacy and social attitudes [6].

In the context of students' spiritual attitude, there has been reported that spirituality and religion are important sources of strength as a source of inspiration to adapt to the surrounding environment [25]. In interacting with the surrounding environment, students capture the meaning of building a spiritual attitude based on a patient and tolerant attitude in adapting to various difficulties. In this situation, spirituality enhances individual understanding to overcome condition and overcome problems. Individuals who believe in spirituality seek God's grace and feel God helping in a difficult time. This courses students to have more control over the situation, more active in dealing with events and more committed to their duties. They are generally more psychologically resilient and more active in managing their learning strategies.

Although comparatively, the NOS model was superior compared to DI in physics learning, quantitatively especially the students' critical thinking was still far below the school success criteria. The average value obtained by the NOS group was M = 29.66 and the DI group was M = 24.25 on a 100 points scale, which means they fall in the very low category. This is a challenge for the next especially for the NOS application in learning physics. It was realized that the application of the NOS model in this study was a relatively new thing for the students, so the students needed quite a lot of time to adapt. In addition, the students made changes in their mindset fundamentally, because so far they had been accustomed to traditional learning. In this case, students might have needed more time to change their views on learning with the NOS model [26].

CONCLUSION

The NOS learning model is superior to the DI model in achieving critical thinking, social attitudes, and spiritual attitudes of students in learning physics in class XI of Senior High School 1 Busungbiu in the topics of sound waves and light waves. Critical thinking of students is the impact of NOS learning model, while social attitude and spiritual attitude are the accompaniment impact. A NOS-oriented physics learning in the learning process prioritizes the empowerment of student potential. The application of the NOS model as an implementation of the SCL approach should be able to maintain and improve the quality of the process, so that it can give a main impact optimally on the students' critical thinking. The results obtained now only reached a very low category of achievement (M = 29.66 on a 100 points scale). The impact of good learning will produce attitudes as a result of a better accompaniment impact.

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