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Article

Physics Teachers' Perceptions about their Judgment within Differentiated Learning Environment: An Implication for Technology Implementation

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Abstract: There is a national shift in the new Indonesian curriculum to employ differentiated learning approach in addressing diversity of students' needs and abilities. Teachers' judgment obviously corresponds to the duty that takes physics teachers to monitor their students at individual level. Within Indonesian physics education research (PER) context, empirical study that has addressed this subject is still lacking. To fill this gap, eight Indonesian physics teachers' experiences and limitations about their judgment within differentiated learning environment has been investigated through phenomenological study. Physics teachers were voluntarily recruited after they have declared their endorsement and personal consent to participate in the study. Our participants were distributed over several teaching experiences, geographic regions, and ICT experiences. The latter experience might be taken into account since, through this study, we would project upcoming developmental research about engaging recent technological approaches to cope limitations of teachers' judgment. Online semi-structured interviews (~ 50 min) were conducted by the first author (P.H.S.) to all physics teachers. Other authors contributed in reviewing the interview protocol (E.I. and H) and training the first author's pilot interview (H.R.). Model of teachers' thought and action was implemented to uncover physics teachers' experiences and limitations in making judgment within diverse students. Findings revealed that physics teachers have conceded that they should adapt learning process in order to meet heterogeneous students' needs. Personal observation has mainly informed teachers to identify students' differences. After students have been identified, they creatively designed learning transformations to accommodate spectrum of students' abilities. Nevertheless, we discovered several limitations encountered by teachers particularly in terms of judgments' equity, accuracy, and their workload. To overcome this, teachers indicated various and supportive attitudes about technology implementation to assist their judgment. Implications for technological development was provided to address obstacles during the teachers' judgment.

Keywords: physics teacher; perception; judgment; differentiated instruction; technology

1. Introduction

One pedagogical competence that should be performed by teachers is their ability to measure the extent to which students have achieved their learning outcomes [1–4]. Teachers' assessment associates with their judgment to their students [5]. Teachers' judgment is the main source of information how students' learning has been progressing. It will guide teachers' decisions in preparing learning treatments such as instructional strategy, learning sequence, content complexity, and difficulty level of the assessment that they will administer [6].Teachers' judgment is determined by early identifying differences of students' abilities in the classroom. Students who are judged as more capable one will be awarded more advanced learning than lower performing students [7–9]. Therefore, teachers' judgment is imperative to be further acknowledged, particularly within heterogeneous students' abilities and backgrounds.

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Facilitating diverse students' characteristics is one aim that is being resonated within physics education research (PER) community [10]. Diversity in physics is our expectation in creating more inclusive physics learning to motivate every individual student. Our PER scholars have established several learning reforms to promote this intention [11]. Recent study by Dunleavy, et al [12] has developed multimedia resources in the form of one-minute videos and short text summaries that have made students able to organize their learning according to their own mental framework. Moreover, the well known scaffolding approach has been widely implemented within PER community in several parts of the world [13–15]. Scaffolding approach assists students' learning through self-determination pace to plan, to monitor, and to measure the extent to which they have been progressing in their physics learning. Diversity in physics has been promoted through other studies including adaptive tutoring system [16,17], computerized adaptive test [18], and employing machine learning algorithms [19–21].

Indonesian PER scholars recently are also being encouraged through a national call to promote differentiated learning that is recommended by the recent policy of the new Indonesian curriculum [22]. This approach is considered capable of nurturing the different students' needs. Differentiated learning will lead teachers to make judgment on recent individual students' performances [23,24]. Teachers' judgment have a vital role in the implementation of differentiated learning. This approach requires information about both the diversity of students' prior background and current learning performance that should be obtained through teachers' judgment. Teachers' judgment associates with the extent to which teachers are able to monitor their students' learning progress at individual level [5]. Students' development at individual level is a key feature of the implementation of differentiated learning in the physics classrooms.

Within the Indonesian educational context, our diversity in physics is represented by zonation-based students' enrollment policy in basic and secondary education [25]. Students are only allowed to enroll for the school whose distance is closer to their home. This selection schema relatively has made our physics learning more heterogeneous than the former circumstance. Therefore, differentiated instruction is recommended by the government to address those students' diversity. Nevertheless, to the best of our knowledge, we have limited resources to study how our Indonesian physics teachers approached differentiated learning. Moreover, corresponding teachers' judgment study is still unanswered within Indonesian PER context. Therefore, this study would contribute to reveal our initial issue about physics teachers' experience in undertaking judgments and approaching differentiated instruction in the context of Indonesian education.

Moreover, judgment begins with monitoring of students' progress throughout learning process. This task requires teachers to provide continous observation to their students. However, students' observations typically discover limitations [26]. To comprehend our understanding about the aforementioned issue, we should contemplate limitations experienced by teachers when undertaking judgments to individual students. This knowledge is imperative to be studied since there are developing digital technologies such as machine learning, educational data mining, and learning analytics [27,28] as teachers' support systems that can assist them to overcome the obstacles.

This article is categorized as preliminary research since authors initiated the effort to investigate physics teachers' experience and limitations in making judgments as a basis for future developmental study. Phenomenological study has been used to investigate the extent of physics teachers' experiences and limitations in making judgments over the time. To achieve those goal, this study is guided by two following research questions :

RQ1. How are the physics teacher's experiences in judging diversity of students' performances ?

RQ2. To what extent are limitations that teachers encountered in making judgment for individual student ?

The findings contribute to an implication of future technology development for teachers' judgment. Teachers' experience that have been discussed in this article should inform best practice in making judgment for general audience in the educational field.

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This study also addresses the context of Indonesian new curriculum that is being recommended as well as recent technology that is potentially approached for teachers' judgment. We expect that our findings might correspond to the new Indonesian curriculum and challenges to address students' diversity. Eventually, we provide future direction to employ recommended recent technology as teachers' support system to overcome limitations in making judgments that were discussed below.

2. Methods

2.1. Study design

Teachers' judgment is pedagogical routine that should be managed by our physics teacher. We assert that they have professional competence to maintain monitoring activities during the learning process. Teachers' judgment engages monitoring tasks at individual level [29,30]. Qualitative study is considered as appropriate research design to explore how physics teachers' experience and limitations in making judgments about their students. Phenomenology is a qualitative approach that aims to find essence of one's experience about certain phenomena [31]. Experience and limitations of Indonesian physics teachers in approaching differentiated instruction with their ways were extracted as our basis to develop technology to address discovered limitations.

2.2. Participants

Eight high school physics teachers (three males and five females) were investigated. They came from several parts of the Indonesian archipelago. Majority of participants were recruited from Javanese people (N = 5) since this island has the most Indonesian population (40%) based on the recent census [32]. Hence, it is reasonable to specify larger proportion than the other regions. Seven teachers were junior physics teachers who have less than 10 years of teaching experience. There was a teacher who has more than 10 years of teaching experience and several experiences in developing computer enhanced learning technology. The attribute of ICT experience embedded to participants associated with the implication of our study that find out how teachers overcome their limitations, one of which is through current digital technology. Recent study by Guillén-Gámez et al. [33] reported that ICT competence could be influenced by pedagogical experiences that manifest how our physics teachers approach their perceptions.

Participants were recruited voluntarily by the first author (P.H.S.) through private platform. Research networking was our main channel in tracing possible participants who are willing to join this study. Participants who have the opportunity to be explored in this study should meet certain criterias, including working as tenure physics teacher for at least 2 years and having insights about teachers' judgment in physics learning. After the candidates have been listed, we privately inquired the teacher candidate's acceptance to participate in the study. If they declared that they were compliant to join as participant, the researcher then scheduled an online semi-structured interview (~50 minutes) which was conducted and recorded through the cloud meeting platform.

2.3. Data collection

The first author was the main interviewer in the data collection. To maintain consistency in understanding each teacher's experience, we scheduled one day for one interview. As soon as the interview was conducted, we directly transcribed recent recorded conversation. This was performed as our initial understanding of what has been discussed. It also could construct our understanding and consideration about physics' teacher experience that was being investigated. If the researchers early understood what has been discussed, we could evaluate what questions that are accidentally out of topic or whether there are missing topics that have not been explored but vital to answer the research questions. For further additional inquiries, we requested their permission to seek some follow-up questions through an instant messaging application.

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Interview protocol was designed by the first author and reviewed by other authors. The second author (E.I.) is a physics education professor, particularly on assessment, who has more than 20 years of teaching experience. Other authors (H and H.R.) are professor in the field of educational measurement. They were involved in evaluating the list of questions in the interview protocol draft and providing advice to the first author pilot interview. We realized that, in its development, the interview protocol was not constant. It was always adapted continually dealing with emergent participants' experiences in making judgments of their students. Prior to the actual interview, the first author conducted a pilot interview with the fourth author to evaluate technical issues of the interview. The results of this training were then observed by the fourth author to evaluate the interview technique that had been performed by the first author.

In this study, the teachers' thought and action model of Clark & Peterson [7] was assumed to be able to reveal physics teachers' experiences and limitations in making judgments within differentiated learning environment. This theoretical framework was proposed to explain the teacher's role as decision maker during the learning process. Therefore, in addition to reporting the experience, we endeavored to dig deeper about teachers' efforts to overcome their challenges. Teachers' judgment should be in accordance with their decision making [34]. There are two main domains in this theoretical framework, namely teacher's thoughts and actions in learning. These two domains appear to correspond constraints and opportunities in classroom setting (diversity od students (RQ1) or limitations during making judgments (RQ2)). Physics teachers were considered always encounter constraints and opportunities in designing and conducting physics learning. They then should think through decisions making or judgments and make actions to overcome their constraints and opportunities.

To answer RQ1, teachers' experiences were investigated on how they perceive the diverse characteristics of students and how to accommodate them. Table 1 presents a sample interview protocol that has been designed through the theoretical framework. We commence the interview by investigating teachers' observations of heterogeneous student characteristics due to zonation-based enrollment policy within Indonesian education. Thereafter, teachers confirmed how their knowledge about differentiated learning and their actions to adapt physics learning with discovered students' diversity.

Table 1. Interview protocol designed from model of teachers' thought and action.

No	Theoretical domain	Question example
1	Constraints & opportunities	Zonation based enrollment rule is being implemented within Indonesia's education. In your opinion, are there any changes towards your physics learning ?
2	Teachers' thought	Have you ever heard of differentiated learning? So far, what are your opinions regarding this matter?
3	Teachers' actions	The heterogeneity of students in the classroom is diversity that exists in the learning process. How do you manage students' diversity during the learning process?

Henceforth, our RQ2 was purposed to deepen our investigation which has been conducted on RQ1. In this aim, the next questions were several limitations experienced by teachers during their "action" in RQ1 (see point 3 in Table 1), lesson adaptation with heterogeneous student characteristics. Therefore, the same theoretical framework should also be appropriate to explore RQ2. As was done before in the RQ1, teachers' actions to address their obstacles were also investigated. Particularly, we consider the latest digital technology that might be employed (according to teachers' knowledge and experience) when making judgments to their students. Therefore, we oriented the interview of RQ2 about the recent development of machine learning and learning analytics to address obstacles in teachers' judgment. The knowledge extracted from this study would be

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expected as introduction for upcoming developmental studies to design teachers' support system in managing their judgment to students' diversity.

2.4. Data analysis

In each interview, recorded conversation data was constantly maintained as audio files (.m4a). Indonesian transcription engines and corresponding regional languages, however, is still currently limited. In fact, our participants are at least speak 2 languages, Indonesian and their ethnical languages. It could be shortcoming if we rely solely on a transcription machine. Therefore, we determined to transcribe manually. Our transcripts were maintained as text format (.txt). Content analysis then was conducted through RQDA (R-based Qualitative Data Analysis) package [35] within R language [36] to assist codings' management of each transcript's segment. This open source library is actually no longer available in the recent version of R language 4.1.3 (One Push Up) [36]. Fortunately, we could still employ the portable version of RQDA in which the suitable R version for RQDA has been embedded. We could download it via developer's GitHub [37].

The first stage of qualitative data analysis was identifying attributes embedded to our participants. We classified our participants within teaching experience, geographic region, and ICT experience. We took ICT experience into account because it associates with our findings and implications that we put forward about technologies that teachers might approach in doing judgments. Second, open coding was analyzed by iteratively reading and interpreting every segment of the participant's experiences from the transcripts. Third, a collection of coding that has been marked was then interpreted in depth and repeatedly to construct it as categories about physics teachers' experience and limitations in judgments' making. Currently, we have yielded a codebook as researchers' basi to answer our two research questions. Through several focus group discussions with three authors, the codebook might be improved based on suggestions given by other authors. In addition to our coding agreement among the authors, we also conducted member checking with the participants. Transcripts were returned to them and they were allowed to verify and to comment (if needed) how the transcript mentioned their thoughts and experiences. Analysis results and manuscript draft of publication were also consulted among the participants. This was expected that our findings have represented their experiences and limitations on teacher judgments in this study.

3. Results

Model of teachers' thought and action has extracted physics teacher's experience in making judgment and their limitations in supporting students' needs. In this section, our answers to the proposed research questions are explained within three categories based on the theoretical framework. Then, each category is elaborated through several subcategories of the participants' conversation samples. In the first domain of constraints and opportunities, we explored physics teachers' experience on how they identified heterogeneous students' ability (RQ1) and what limitations that they experienced in observing diversity (RQ2). In the second domain of teachers' thought, we investigated how teachers perceived the differentiated instruction approach that is recommended by the new curriculum (RQ1) and their knowledge about technology enhanced efforts to overcome their limitations in making judgments (RQ2). In the second stage, the main investigator persuaded physics teachers to described their "thought process" about their role as individual student evaluator in order to make physics learning more responsive towards students' needs. In the last domain, they explained "action process" in students' monitoring that has been carried out as a teachers' effort to deal with diversity during the physics learning process (RQ1) and how they overcame shortcomings during judgment in the physics learning process (RQ2). The organization of categories' presented below represents the teacher thought and action model of Clark & Peterson [7] and how physics teacher approached in their experiences. Evidences from each category are explained by including corresponding conversation segment. Participants' names (Desi, Fika, Fitri,

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Hendro, Narti, Tinah, Yoga, and Yono) have been anonymized arbitrarily to maintain and respect participants' privacy as our ethical clearance in this study.

3.1. Physics teacher's experience in judgments within differentiated instruction (RQ1)

In answering RQ1, phenomenological study has extracted three main categories driven by model of teachers' thought and action. Physics teachers were aware of their constraints to adapt physics learning with students' diversity. Teachers' judgment was considered mandatory to adjust their learning environment to meet students' ability that has been observed by the teachers' judgment through several channels such as personal observation, task observation, or peer observation. According to their observation, teachers designed several learning reforms to adjust it. Our results confirmed that teachers typically already have sufficient understanding about the concept of differentiated instruction. In addition, they realized that there was potential data to mine that assist and contribute to their judgments. Teachers' institutions have also actually provided support that teachers admit have directed them to deal with physics students' diversity.

3.1.1. Category 1 : Constraints and opportunities

In this category, physics teachers conceded that students' differences are tangible learning constraints as well as, at the same time, challenges that might be dealt with. As declared by the results of interviews that would be discussed in this category, physics teachers actually had an awareness of students' diversity which might prosecute teachers to adapt their learning throughout students' need. Teachers also confirmed that schools have taken part for their professional development process in approaching differentiated instruction. Physics teachers emphasized that judgment is their main task for learning management. Therefore, they concerned that this task is important in order to support individual students during the learning process and students' assessment.

3.1.1.1. Students' difference

Physics teachers underlined that there are gradation of students' ability during physics lesson. Hendro should ensure that physics learning might be able to gain students' need for whole spectrum of ability. His notice should just not be given to the middle students in the normal manner. Hendro admitted that, *"Teaching is unique. Compared to the old days when I was student, my learning was quicker. However, it evolves now. I observe that I tend to pay more attention to low performing students than high performing students. I sometimes even wonder whether these students feel cared for or not. Maybe, in their heart, they are feeling bored because my learning has no significant progress"*. Ideally, teachers' judgment might be effective when they could reach whole students' ability.

3.1.1.2. Data avaliability

Teachers assumed that their judgment could be decided through the assessments they administer routinely. Information availability that has presented through their assessment process should enrich teachers' attention about students' development at individual level. As Narti encountered, *"My second suggestion might be our assessment should be continuously designed. It is because our learning should ascertain student's development through continuous assessment. Subsequently, assessments should be aimed for facilitating us to judge students one by one in large class size"*.

3.1.1.3. Institutional support

Teachers' knowledge about how to make judgment was not only obtained after they pursue academic degree and teachers' training. Physics teachers confirmed that they have received pedagogical support for knowledge development through school program or their teachers' community. This program should have previously been discussed with the local office of education and also regional teachers' forum. Fitri appreciated that, *"What's that... it's reflective teacher program, but not all of them participate. Moreover, zonation policy for*

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the first time was implemented during pandemic outbreak. Teachers' training in accordance with the government's destiny was hampered. I heard that other teachers also had participated in program about learning modules or worksheets development for students' activities".

3.1.2. Category 2 : Physics teacher' thoughts

In this category, the researcher encouraged physics teachers to argue about differentiated learning for physics education, the way how teacher's judgment could support, why teachers should consider this approach, as well as implications for physics learning and assessment practice. The results of interview highlighted that most of our teachers have been familiar with this learning approach eventhough they did not claim as their teaching practices. Monitoring students was recognized by physics teachers as an important task in facilitating diverse students' ability. Differentiated instruction requires teachers' competence in judging and finding out current students' progress. Judgment results are also contemplated as having impact to their assessment practice.

3.1.2.1. Knowledge about monitoring and prediction task

Fitri declared that, "For students' ability, it implies that, without actually following the assessment process, we actually have been intuitively informed about student's prior background. Since we began to teach, we actually already analyze our student's background, prior abilities, and their limitations". From Fitri's statement, it implies that teachers have represented their role in making judgments during the learning progress. Judgment might be supported by information obtained through the monitoring process hence teachers were enable to judge predictions. Prior ability is one factor that teachers noticed from their students' background within physics classroom. This factor was conceivable to impact the teachers' judgment towards the students. Teachers typically have put their expectations down about their students' retention during the physics learning.

3.1.2.2. The importance of teachers' judgment

Physics teachers perceived that their judgment represents pedagogical task as a decision maker. Yono narrated that, "In my opinion, our judgment is highly impactful, actually. From this judgment, we then actually determine what treatment will be approached afterwards. If, for example, there was disconnected pupil to be handled. From this thing, it informed us that physics should be discussed more simply". Physics learning management might be tailored to deliver students' characteristics they discovered. The proper decision obviously lead to the robust effect to the students. Teachers' judgment then would produce learning effect by students after participating in physics learning.

3.1.2.3. Teachers' judgment for assessment

In addition to influencing the learning treatment that is approached by physics teacher, they argue that judgment was essential for assessments' consideration. Within context of the new Indonesian curriculum, Hendro discussed that, *"The new curriculum design recommends the differentiated assessment. It represents that, for the brighter student, the passing grade should be higher, for example, ninety five point, arbitrarily. In case of lower performing student, sixty point then should be considered as their peak. Therefore, assessment is more tensile. As we know in the current context of assessment system, successful students might have to obtain certain grade point, typically, for instance seventy five. I have heard would be like that from several resources"*. Through the institutional support, as explained on aformentioned category, physics teacher has been informed that new assessment paradigm would be adjusted to adapt responsively based on students' ability which were observed by judgment. From the Hendro's experience, his judgment to the students could interfere how teachers create expectation towards their assessment standards.

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3.1.3. Category 3 : Physics teachers' actions

In this category, physics teachers discoursed about their actions' experiences in providing support for students' diversity which have been mainly discussed above, both designing responsive learning transformations and the implementation of three monitoring channels that they implemented. Various learning transformations have been designed by our physics teacher creatively, particularly in fostering cooperative group discussion. Their efforts might be determined through exhaustive teachers' observations that are collected through three main channels, namely personal observations during the class, task observations that have been assigned by the teacher, or peer observations through informal discussions with other quantitative subjects' teachers.

3.1.3.1. Learning transformation

Heterogeneous of students' abilities are spread within ability spectrum that makes teachers to provide learning assistance for their students. Cooperative group discussion was deemed appropriate to address this subject. They could be helped by students with higher abilities as a tutor in delivering physics learning to low performing students. Hence, physics education have been attempted to maintain in order to meet high and low students' ability (differentiated learning). As delivered by Fika, *"For the management of students' diversity, I sometimes approach students' groups that was own designed to adapt learning throughout students' diversity. Although it might be imperfectly implemented, my efforts have been made so that this diversity can be accommodated by the formation of students' groups".*

3.1.3.2. Personal observation

To supervise the learner developments, physics teachers typically conduct personal observations through various channel. Tinah confirmed that, *"If you just observe the students, actually, it's not difficult for me. Fortunately, I'm assigned as a class advisor in my school and I have some occasions that enable me to privately talk to students. I then take note about their difficulty, like that. It can be explored more deeply. However, this case is subjectively in my experience"*. Observation is a mandatory task that is routinely managed by physics teachers. Tinah's experience articulates that teachers actually feel no difficulties to make personal observation if they are supplemented additional information outside the classroom. The information obtained from their observation serves as teachers' basis for judging students' diversity and designing learning adaptation.

3.1.3.2. Task observation

Students' behavior could typically be studied through their commitment of assignment given by the teachers. Teachers' expectations to students could be influenced through this channel. They could argue that assignments are part of the assessment point throughout the final exam. Submittance of assignments are typically related to their performance throughout the semester. Fitri described, *"Sometimes I solely considered assignment submittance from students. For example, I gave four assignments. I could clearly make judgments when there were students who only submitted as many as three assignments. Even my warning was neglected and they still left the learning. From this, my prediction conclude that he/she was inadequate on physics. You can already predict what the students will be like".*

3.1.3.3. Peer observation

The social competence of teachers could be reflected through this observation way. Collaboration is needed to create effective physics learning [38]. Not only attempting personal or task observations, teachers often share their observations with other teachers either within the same subject or different subjects through peer discussion outside the classroom. Desi told that *"Usually it was not just on physics. For instance on mathematics or other quantitative lessons, our students' ability is lacking or still tends to be low".* Information obtained from peer discussion could serve as reinforcing information for teachers'

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judgment. Therefore, other supporting evidence have augmented teachers' understanding about characteristics of their students.

3.2. Limitations of teachers' judgment within differentiated instruction (RQ2)

In answering this second research question, we enriched our knowledge from RQ1 by deeper investigating physics teachers' limitations when making judgments within differentiated learning environment. Among the three components in the model of teachers' thought and action [7], physics teachers confirmed their most experiences about constraints when physics teachers dive into students' learning, particularly how they should identify students' needs at individual level. Furthermore, we then oriented the discussion to discover how teachers' knowledge presents to overcome their constraints during the teachers' judgment. Particularly, we explored their understanding about the existence of recent development of artificial intelligence such as machine learning and educational data mining that would be informed as implication of this article for upcoming development. Experience in this category might also associate with the "data availability" subcategory in RQ1 above since data is the knowledge base in building machine learning algorithm. As we mentioned earlier, the context of teacher's ICT experience hence clearly influences how teachers understood what technology that could be approached to overcome their limitations. Eventually, in order to wiser captured our teachers' experience, we also investigate teachers' practice that have been taken as their actions in strengthening the accuracy of their judgment in physics learning.

3.2.1. Category 1 : Constraints and opportunities

We maintained the same theoretical framework in understanding teachers' limitations when making judgments about their students within differentiated environment. Teachers greatly confirmed their constraints during they are observing students' characteristics at individual level. Our findings revealed that, to date, physics teachers still tend to employed informal data collection when making judgments even they have adequate knowledge discussed above. They actually realized the weaknesses in terms of accuracy and equity of teachers judgment through this way. The limitation in the form of teachers' workload was also still presented through our discovery. Observing students at the individual level and maintaining teaching schedule and other additional duty were relatively difficult to manage at the same time. In addition, curriculum shift led to future challenge for their educational routine in teachers' judgment. This would also implicitly impact the available data that should be considered through the learning reforms. Therefore, re-adaptation of teachers' judgment should be attempted.

3.2.1.1. Informal data

Hendro admitted that his observations have never been carried out based on sophisticated data analysis. He confirmed, "For your information, I have never really done that way. We're just marking students. For example, there are only four most dilligent students in tenth grade. There are ten middle students. Then, a total of fifteen students with lower abilities, just it is. And then, those students should follow my remediation program. For the advanced calculation, it has never been implemented. Just mark students. Student A, Student B, Student C, as you know". Hendro's experience illuminated that students' judgment was made informally by counting students characteristics in the range of cognitive ability scale.

3.2.1.2. Limited data resources

Physics teachers required a support system to assist them in observing students' learning progress at individual level. In the context of Indonesian education, the e-report system that has just been implemented currently was inadequate in providing information about students individually. The previous educational report system was recognized as having more advantages to monitor students at individual level. As Tinah

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concerned, *"If it's like the old assessment report (I remember when I was in elementary school). If I'm not wrong, the elementary school report is handwritten, right? And the description of each student was handwritten by the teacher. So, we can find out students' development one by one. However, for the e-report nowadays, it can't be one by one, it can't be"*.

3.2.1.3. Curriculum shift

Physics teachers suggested that we might participate to the curriculum change that is currently being disseminated before we make teachers' judgments. *Yoga said, "Yes, considering about data availability, let us follow (the curriculum) first. Because it is actually still continuously updating. You should not decide that it would A-B-C-D. You should try to learn what the government wants first and where will their policy go next"*. Curriculum shift could reorganize some of the previously available data with different assessment systems. Yoga recommended to follow the dissemination directed by the national government.

3.2.1.4. Judgment accuracy

Physics teachers argued that observational assessment or teachers' judgment is solely the preliminary of their assessment process. Yono explained that, *"So, I see that attitudinal observation is only the first step of my criteria actually. For example, we implement self assessment or peer assessment between students, then we still have to examine it by considering their cognitive abilities. Maybe from the assignment or the final exam"*. Teachers actually, however, doubted their judgment accuracy if that was only derived from their personal observations of students. The inferences of their personal observations should be verified through other measures such as self assessment or peer assessment by students' participation. Then, Yudi also believed that cognitive tests should be calculated.

3.2.1.5. Judgment equity

This subcategory associates with Hendro's statement that he wondered what his students perceived about physics learning in which he currently tend to accomodate low performing students (see Category 1 of RQ1 above). This constraint implied that physics teachers were unable to warrant whether their personal observation of students' differences has been ideally adequate for all students. There was an impression conveyed by Fika that brighter students frequently complained her since low performing students were lack of involvement. She was afraid in case their learning will be out of control since the high performers were preceding the slower students. Fika confirmed, *"My experience was the high performing students complained me that their low performing friends were not actively involved in class. Hence, the higher students' learning preceded their slower friends"*.

3.2.1.6. Teachers workload

Ultimately, teachers described their serious concern about workload in order to ideally approach the concept of differentiated learning. Desi suggested that, *"But there are a lot of students, right? So my coverage might be in the limited range that would be judged immediately. I imagine best practice might be in several meetings since it would be hard to monitor individual students at every single day and, you know, we have numerous students that should be managed"*. The high teachers' workload was highlighted in this subcategory. Teachers have a lot of responsibilities beside making judgment. The number of classes and students that might be observed could threaten judgment accuracy and equity above. This finding should imply that teachers requires a support system in making judgment.

3.2.2. Category 2 : Physics teacher thoughts

In this category, novel information might be revealed from the results of this phenomenological study. To the best of our knowledge, there is no similar research on recent technology development, particularly machine learning, educational data mining, and learning analytics that consider qualitative investigation prior to the developmental agenda. Suggested technology in the below discussion was addressed to overcome

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aforecited teachers' constraints when making judgments. We have explored physics teachers' knowledge to approach possible way to design technology to address their issues. Therefore, ICT experience and teaching experience, as previously explained, would greatly influence how teachers perceived those experience. Yoga is one of our participants who has 10 years of teaching experience than the others. He was frequently involved in digital activity. He has developed numerous product such as 3D animation, Android based software, and internet of things on physics laboratory. From his experience, he was quite cultivated how technology could enhance physics learning and instruction. Recently, he was developing a computer based test to administer online assessment for thousands of high school students at 11 public high schools during the COVID-19 constraint. Development of artificial intelligence (AI) technology such as machine learning, educational data mining, and learning analytics also have been explored during his spare time among his teaching schedule and additional job.

3.2.2.1. Technological insights

Among our eight physics teachers, few of them have discovered machine learning exclude Yoga that routinely learn it independently. Presence of ICT experience might be considered to carefully interpret their approach to this technology in making judgment. In the interview, Fika just found out that machine learning could be approached for educational practices. Fika *narrated, "I am literally slighly familiar with that. But if it can be implemented for learning, I have no experience. Instead this may be the first time I have heard that artificial intelligence could be applied for teaching and learning decision".*

3.2.2.2. Technological attitudes

Supportive attitudes have been exhibit by them towards their recommendation. However, some notes were proposed by Hendro that should be taken into account for our machine learning development on teachers' judgment. He argued that construct validity of the learning outcomes measurement tools should be examined among the schools and teachers. Each school obviously has different bacgrounds that implicitly affect teachers' space. Hendro said, *"The data is based on the students' behavior. The weekly test of certain topic, for example eighty, vector eighty five, then machine learning predicts students' performance. Teachers usually administer unstandardized items, you know. It was different from college scholars who provide research based assessments that are valid, reliable, or whatever. Hence, their measures might represent students' ability. For your information. I admit that most of the teachers occasionally design physics problems about what comes into our heads and we give it to our students. Several books typically were also adapted then engage university enrollment test also. We typically set this kind of psychometric analysis a side".* Hendro's notes might be assisted through teachers' community in fostering cooperative efforts in this issues.

3.2.2.3. Technological resources

Yoga was merely one talented teachers with certain ICT experiences. Yoga gained sufficient knowledges through independent inquiries outside the educational job. As a physics educator, he had awareness to follow recent development of digital technology during this time including machine learning development. However, high teachers' workload above was admitted by Yoga also inhibit him to explore more about machine learning technology in teachers' judgment. For the initial effort, we appreciated his attempt to approach technological resources for his knowledge. Yoga declared, *"I have heard machine learning and I have found it on Google. You're planning to study so it's kind of intrigued me. It's just because I have a lot of teaching schedules and so on. For now, I have no clues, but, I see it on Google cloud platform. It was interesting to be learned. But, the resources were not in Javanese, hahaha. So, I have to explore a bit more about that, you know".*

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3.2.3. Category 3 : Physics teacher actions

Constrains that have been observed by physics teachers above were addressed by their actions' experiences in this category. Limited technological resources that have been arrived to them, however, made this was slightly irrelevant to our implication of this article. However, this had been considered based on our discoveries on the teachers' knowledge about machine learning technology formerly. We conveyed truly appreciation to our physics teachers' action in conducting other cognitive assessment and associate it with the previous observational results in making judgment.

3.2.3.1. Cognitive test consideration

To improve judgment accuracy that has been discussed in the first category, physics teachers experienced that they might reconcile former results of personal observations and other measurement methods such as cognitive tests. Information support through cognitive tests was considered for enable them to strengthen the teacher's subjective judgments previously. Yono said, *"I think that attitudinal assessment or observations were my preliminary assessment but still have to be proven by cognitive assessment"*.

3.2.3.2. Data matching from learning experience

Several learning transformations in their actions to adapt with students' ability were considered as imperative factor for adjusting teachers' judgment. Narti has implemented laboratory activities and project based learning for diverse students. Narti described, *"There were sometimes those who are talented in experimenting or making projects. There are students who are inactive in classical interactions then evolved more passionate on project based learning. Therefore, at that time, the former judgment should be adjusted. Projects, well, that's what makes them more interested on physics. Other case on demonstration task and they were found more active. If my learning was only one direction, sometimes, meke them passive. Something like that. Not the same situation, different. For example, it fosters process skills"*. This result implies that, in one case, students may underperform because they have different characteristics that are not in line with the current learning approach. However, through other learning approaches, students tend to became more involved.

3.2.3.3. Following out class observation

To address aforementioned high workload of our physics teachers, Tinah suggested to conduct additional observations outside the learning hours to strengthen judgment evidence. The situation is favorable since Tinah was assigned as class advisor. Students would usually be more comfortable sharing with their advisor. Through this way, thus, students' problems should be more accurately identified by teachers. Tinah confirmed, *"For the case, not every class. We sometimes have spare time for certain occasion. For example, we wonder students that seem like less focus during the class. Then, I try to privately talk to them. We'll talk outside of class. I conduct out class sharing for enriching information for judgment"*.

4. Discussion

Teachers' judgment on the learning process was carried out to improve the quality of learning. This activity is closely connected to teachers' monitoring process of the students' progress, including how teachers expects and predicts students' performance during learning process. In this study, model of teachers' thought and action has explained how three components could explain physics teachers' experiences and limitations when making judgments within differentiated instruction environment. Students' diversity is a topic that was recently considered within PER community [39]. Physics learning should be inclusive and it might be accessible to create more effective physics learning [10]. In this article, we have found that our physics teachers have recognized the constraints and opportunities during students' learning. There are three main channels that teachers often employ to identify students' differences on physics learning, namely personal observation, task observation, and peer observation. Teachers' judgment is important to

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ensure our physics learning could meet students' development. In addition to these methods, previous studies reported that teachers also often conduct students' monitoring processes through students journals [40,41]. However, there were some limitations that we underline in the study results, namely intuitive and informal results which sometimes threaten the accuracy and equity of teachers' judgment. Observations, through this way, might be easier to follow but the obtained judgment could not for generalization because several limitations are still present [42]. The practice of teachers' judgment discovered several drawbacks such as the accuracy, equity, and teachers' workload which could interfere with their opportunity to pay attention to each individual student.

As a teachers' support system in making judgment, data driven monitoring process should be an alternative way to reduce previous teachers' constraints. To improve the quality of judgments that teachers have made, we could consider the opportunities of online learning habits that have just approached us to date. The COVID-19 pandemic since the beginning of 2020 has forced education around the world to get into online learning mode [43–46]. This challenge implicitly offered opportunity for our physics teachers to explore their potential in overcoming their limitations on teachers' judgment. One could recognize learning management system (LMS) is a very large channel for collecting educational data such as assignments, quizzes, projects activities, laboratory works, or even prior grades that have been obtained before coming to class. As mentioned earlier above, data is the main information then teachers were able to make judgmentst to their students' diversity. Therefore, our physics learning should benefit from the challenge of LMS application.

Broadly known, current limitations of pandemic learning, at the same time, promote great ideal on remote or hybrid learning. The mixed method study published by Herodotou et al. [28] has implemented predictive learning analytics (PLA) in a large-scale open university in the United Kingdom. This research was a series of developmental projects that the authors have carried out since 2017 to augment hybrid learning which is the main feature of the learning process provided by their institution. Authors reported that the implementation of PLA by teachers could significantly affect students' performances. The more often teachers involved PLA in the learning process, it was proven that they were able to provide support to students. Based on the qualitative phase, the authors suggested some ongoing support to teachers in the PLA implementation phase and translating the information. From this multi-method study, the author concluded that PLA is a source of information that is able to provide resources to improve learning, especially for distance learning.

The technology that we suggest in this article could be assumed as the implication of our study. We recommends recent development of artificial intelligence (AI) to address limitations discovered in teachers' judgment. One of the fields of AI study, namely machine learning (ML), is a predictive model that has recently become novel attention in the assessment of physics learning [19–21,47,48]. Implementation of ML studies for educational purposes, namely educational data mining (EDM) and learning analytics (LA) employing ML models to develop predictive system to monitor students' learning. Hence it would serve as teachers' support systems to overcome judgment accurary and equity [49–52]. Therefore, this ML and EDM technology should be involved in teachers' judgment. A large body of literature has widely applied this idea to be implemented in physics learning. However, to the best of our knowledge, literature that has been addressed about teachers' limitations in teachers' judgment is still lacking. There are rooms for developmental study to implement ML for high school physics learning because some discussed studies above were mostly at higher education institutions.

This research has been entirely constructed through the theoretical framework offered by Clark & Peterson [7]. We are aware of the possible limitations from this decision since the teachers, perception of using and implementing the suggested technology could be unanswered from this theory. To address this gap, we suggest that future researchers could approach other theories that are widely implemented in the development of digital technology namely theory of acceptance model (TAM) [53]. This theory was proposed to

model how the technology implementation could be accepted by users in our work. TAM emphasized more whether technology development is able to understand external variables such as user attitudes towards their benefits and ease of use.

According to previous literature inquiries, studies in our subject have been dominated by examining quantitative measure of judgment accuracy [30,54–58] for which qualitative investigations through the TAM lens are still limited. Therefore, there is an open space to explore a more comprehensive teachers' experience regarding the teacher's perception of ML application to assist teachers' judgments. Future researchers could also investigate factors that influence teachers' opinions through the TAM framework. This investigation is vital because our teachers are the real user in this technology development to overcome teacher's limitations in making judgments.

The results of study reported in this article are expected to be a consideration that teachers actually already understand the concept of differentiated learning and how to provide support to teachers. Teachers' limitations in making judgment reported in this article are potentially addressed as a baseline for other researchers to conduct further research to overcome them. We suggest that it is time for us to promote data-driven technology that could offer more accurate and fair judgment. Teachers' workload is also expected to be reduced through this teachers' support system. Although, for now, there is no policy that requires teachers to employ machine learning in students' judgment. For this reason, the findings of teacher opinions extracted in this study have implications for giving recommendation to stakeholders in the development of teachers' support.

5. Conclusions

The phenomenology study has extracted Indonesian high school physics teachers' experiences and limitations during making judgments to facilitate differentiated student's needs in the physics classroom. Model of teachers' thought and action has described that there are three domains of the shared teachers' experience. First, teachers considered that students' diversity that are performed by them was opportunities to transform physics learning. Through the support of data availability and school program, teachers have implemented their actions to provide support for students' diversity in the context of differentiated learning. In the other hand, our study reported several teachers' limitations encountered while making judgments.

Second, limitations of teachers' judgment were most recognized by teachers in terms of teachers' workload, judgment equity, and their accuracy. Teachers still considered that their judgment was still an informal decision so that they might be adjusted from other channels such as involving adaptive technology to support judgments. Digital technology suggested as the implications of this research was considered capable of being a teachers' support system in making judgments. The implications of developing machine learning suggested in this study are expected to encourage upcoming research projects to address this issue more comprehensively. Providing support to teachers is our step to improve the sustainability of physics learning.

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