How Can We Support University of Mathematics Education Student to Learn about Design-Based Research?

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Abstract. The industrial revolution 4.0 requires human resources who can design and make innovation in various fields including education. The design and innovation cannot be separated from the role of research. DBR as one of the research methodologies is a bridge between the innovations that are developed with the practice in formal education. Validation in a real context provides certainty that the research design can be used effectively to assess, inform, and improve activity at least in that context. However, many university student have not used DBR in educational research. The results of the questionnaire and interviews showed that many mathematics education students have no prior experience about DBR. In fact, as prospective educators, they should know DBR as a provision in designing innovative learning in for their future career. Therefore, this study aims to describe our step in course about how to support students to understand and be skilled in applying DBR. By emphasizing the student centred learning combined with context-based problems, we have succeeded in guiding students starting from strengthening DBR theory, designing learning that is appropriate to the student context, applying its design in the classroom, and finally, students can produce a valid and innovative learning design.

1. Introduction
Supporting students to master various concepts and skills in their fields that are adapted to the needs of the times has always been an important part of us as professionals academic in higher education. For example in the field of education, [1] stated that in the industrial revolution 4.0, prospective educators must adapt themselves and certain changes to successfully exploit all the potential that exists. Thus, prospective educators are required to be able to do various innovations in learning design. Efforts to prepare innovative teacher candidates cannot be separated from the role of research. Through research methodology courses, one that is believed to be able to make prospective educators more innovative in designing learning is by learning about Design-Based Research (DBR). The involvement of DBR in educational research also has quite strong reasons. In this case, [7] formulated three of them, namely: (a) DBR provides an opportunity for us to learn unique lessons (b) DBR produces practical lessons that can be applied directly, and (c) DBR engages researchers in improving educational practices in an live. This opinion shows that indirectly prospective educators will be trained to be more innovative in designing learning. The same thing is also confirmed by [6] that DBR can help create and expand knowledge about developing, creating, and maintaining an innovative learning environment. Furthermore, [5] stated five characteristics of DBR. First, it aims to experiment with designs to develop theories. Second, the methodology is very interventionist with the research design which is usually a basic test for innovation, so that the possibility of improving education in the form of new
learning can be investigated. Third, having a perspective and reflective component is not separate from teaching experiments. On the prospective side, the design is implemented with the hypothesized learning process and the means to support the learning process. On the reflective side, design experiments are driven by conjecture, where the allegations in the initial design contain the means of supporting certain forms of learning to be tested. Fourth, DBR has a cyclic nature where the discovery and revision can form an iterative process. And fifth, the theory developed must be real activities. Besides its characteristics, DBR has three phases in its application. The three phases are preparation and design, teaching experiment, and retrospective analysis. These phases can then form a repetitive process if the results of the application are not following with the design as shown in the following figure 1 [8][3].

\[\text{CONJECTURED LOCAL INSTRUCTION THEORY}\]

![Cyclic Process in DBR](image)

**Figure 1.** Cyclic Process in DBR

First, the preparation and design phase aims to formulate a local instruction theory that can be elaborated and refined along with the experiment [8]. In this phase, students are required to be able to design the ultimate goal of student mathematics learning in the form of a Hypothetical Learning Trajectory (HLT). HLT consists of three main components, namely learning objectives, learning activities, and hypotheses of the learning process. The hypothesis of the learning process intended here is the alleged thought and understanding of students that will develop during learning activities [10].

Second, the teaching experiment phase, aims to implement HLT that has been designed for classroom learning. At this stage, it can be observed suitability or deviation made by students and teachers of the designed HLT. The data collection is usually done in this phase includes student work, tests before and after teaching, field notes, audio recordings of class discussions, and video recordings of each lesson and final interview with students and teachers [3].

Third, the retrospective analysis phase, consisting of task-oriented analysis and a comprehensive cycle approach. In the task-oriented analysis, we can compare students actual learning data during learning in different classes with HLT. This analysis can be used to increase HLT in the next DBR cycle [3].

DBR cannot stand alone. DBR refers to several types of theories. One of them is the domain-specific theory of Realistic Mathematics Education (RME) which can build a framework in the design process [3]. The existence of this connection is not only the strengthening of the DBR concept that we provide to students but also the concept of RME, including understanding; the main characteristics are phenomenological exploration, bridging by vertical instruments, self-reliance: pupils' constructions and productions, interactivity, and intertwining [11]; leveling modeling activities ranging from task setting, reflective, general, to be formal [9].

As a systematic and flexible design-based research methodology, DBR aims to improve educational practice through repeated analysis, design, development, and implementation, based on collaboration
between researchers and practitioners in the real world that leads to the principles and theories of context-sensitive design [13]. This shows that DBR can connect theory and practice directly. This is a very important part for students when they are facilitated to practice what they have learned in class [16].

Although DBR is important to be mastered by students, there are still many of them who do not yet have an understanding of knowledge or skills in applying it. Many students who have never known even use DBR. Based on the results of the questionnaire at the beginning of learning, 93% of students answered that they did not know DBR. The interviews support the same thing which reveals that most of them are new to class action research, experimentation, and development. This shows that students do not have a good understanding of DBR concepts and are also skilled in applying them.

One way to support students to have a good understanding of DBR concepts and to be skilled in applying them, we apply student-centered learning combined with context-based problems. The role that we do as instructors in student-centered learning is by applying the following principles: (1) teachers do learning tasks less; (2) teachers do less telling, students do more discovering; (3) faculty do more modeling; (4) faculty do more to get students learning from and with each other; (5) faculty work to create climates for learning; (6) faculty do more with feedback [14].

2. Method

This research is a quantitative-descriptive study involving 43 students in one class for one semester. The study was conducted on a research methodology course by applying student-centered learning principles combined with context-based problems. The instrument used consisted of a student's DBR understanding ability test and a field practice observation sheet. Furthermore, the data on the results of comprehension ability and assessment of the implementation of field practices are converted into qualitative data with the following table.

| Score Interval | Category |
|----------------|----------|
| $X > \bar{X}_i + 1,8 \times sb_i$ | Very good |
| $\bar{X}_i + 0,6 \times sb_i < X \leq \bar{X}_i + 1,8 \times sb_i$ | Good |
| $\bar{X}_i - 0,6 \times sb_i < X \leq \bar{X}_i + 0,6 \times sb_i$ | Adequate |
| $\bar{X}_i - 1,8 \times sb_i < X \leq \bar{X}_i - 0,6 \times sb_i$ | Poor |
| $X \leq \bar{X}_i - 1,8 \times sb_i$ | Very poor |

(Widoyoko, 2017: 238)

Description:

$\bar{X}_i$ = ideal average
$X$ = empirical score
$sb_i$ = ideal standard deviation

The activities carried out during the research to support students in mastering DBR can be considered through the following table.

| Activity | Description |
|----------|-------------|
| Strengthening the theory | Students are invited to discuss in groups to rediscover theories about DBR and RME from various references in the form of books and related journals |
| Guidance: |          |
| - Learning design | Students are guided in designing HLT |
| - Conclusions | Students are guided in analyzing and summarizing the results of practice |
| Practice | Students apply the design of learning activities in the school classroom |

At the beginning of the activity, students are given a reinforcement of theories about DBR. This reinforcement is a way to shape new student behavior ([4]). That is, strengthening the theory is not only so that students understand the concept of DBR, but also able to apply the DBR procedure itself
well infield practice. This strengthening process is carried out in the form of group discussions where we give various encouragement to students to be able to actively participate in constructing concepts related to DBR using various references while being able to apply them in the field.

The next activity is guidance which consists of guiding the learning design that is carried out before the field practice and guiding conclusions that are carried out after the field practice. In the initial mentoring activity, students begin to apply the preparation and design phases. Students examine problems in learning, then we direct and encourage them to design innovative activities on HLT. The design of the HLT was then tested on field practice activities. After the field practice ends, concluding guidance is conducted. In this guidance, we direct the results of the application of the design that has been done in the field to HLT conformity.

3. Result
The results obtained from this study consist of an understanding of DBR which teaches research expertise and good mathematics learning design. The research results for each activity are detailed in the following table.

| Activity                      | Result                        |
|-------------------------------|-------------------------------|
| Strengthening the theory      | Students' DBR understanding ability |
| Guidance for learning design  | HLT                           |
| Practice                      | DBR use skills                |
| Guidance for conclusions      | ILT                           |

The ability to understand students' concepts about DBR was obtained through tests conducted at the end of the theory strengthening activities. The test results obtained by students can be seen through the following table.

| Category     | Total Student | Percentage |
|--------------|---------------|------------|
| Very good    | 3             | 6.98 %     |
| Good         | 34            | 79.06 %    |
| Adequate     | 6             | 13.95 %    |
| Poor         | 0             | 0 %        |
| Very poor    | 0             | 0 %        |

4. Discussion

4.1. Theory Strengthening Activity
In the theory strengthening activity, by combining the six principles of student-centered learning, we succeeded in encouraging and facilitating students to be active in group discussion activities. We lead them to rediscover the concepts related to DBR including the understanding, characteristics, use of RME in DBR, and the phase of using DBR through various references both books and related journals. The atmosphere of active and conducive discussion can be seen through the following picture.
In addition to direct observation, at the end of the theoretical strengthening activity, a test was also conducted to measure the students' understanding of DBR. Based on Table 4, the ability to understand student concepts related to DBR is in a very good category with a percentage of 6.98%. Only 79.06% were in a good category and 13.95% were in the moderate category. This shows that the overall students' DBR comprehension ability is in a good category after being given a reinforcement of the theory using student-centered learning combined with context-based problems. The good understanding ability of DBR students is also in line with the statement which states that understanding is one of the competencies emphasized in student center learning ([2]).

4.2. Guidance for learning design
By emphasizing the principle of feedback in its context on student-centered learning, we guide students to innovate in designing learning which is the first phase of DBR. In the coaching activity, students look so enthusiastic as shown in the following picture.

In line with this guidance process, students can produce innovative learning designs with various activities in a real context for students. This innovative design is packaged in the form of a learning
path from the informal to the formal stages. One example of the design of the learning trajectory can be seen through the following picture.

![Learning Line Measurement](image)

**Figure 4.** Learning Line of Measurement

The results of the learning trajectory design by these students are based on the theory of [12] which defines that measurement as a process of comparing the attributes of an object with the same attributes of a measuring instrument. The learning trajectory in this measurement is then further described through the HLT design which is summarized as follows.

**Table 5.** HLT of Measurement

| Learning objectives | Learning activities | Hypotheses of the learning process |
|---------------------|---------------------|-----------------------------------|
| Recognize the length of an object through everyday sentences (short, long) and compare them. | First Stage: Make a comparison Second Stage: Using the unit of measurement model Third step: Using a length measuring instrument | Students measure using a snake ladder box Students measure using a broken ruler Students measure using a normal ruler |
| Using non-standard and standard length measuring instruments that are often used. | | |
| Resolving problems related to the length of the object | | |

4.3. Practice

In the practice activities which are the second phase of DBR, we facilitate students to apply the learning design in the research class. In line with that, the students’ skills in implementing DBR were assessed from two aspects, namely the suitability of the implementation of procedures and aspects of innovative design.

4.4. Guidance for conclusions
This activity is part of the third phase of DBR, namely retrospective analysis. In this activity, based on the suitability of the application of the design in the field, we try to direct students to be able to conclude instructional learning theory or have to revise HLT again and enter the next cycle using the HLT comparison matrix and Actual Learning Trajectory (ALT). Following is one example of a matrix that students have composed.

| HLT | ALT |
|-----|-----|
| Formulation of The Task | Transcript excerpt |
| Conjecture of how students would respond | Match between HLT and ALT: Quantitative impression of how well the conjecture and actual learning matched (e.g., −, 0, +) |

By using a matrix, it is easier to know which HLTs are suitable and which ones need to be revised and then continue in the next cycle. Based on table 5, students are directed to …… ..

5. Conclusion
Based on the results of research and discussion, it can be concluded that the activities emphasized on student-centered learning based on context, can support students mastering DBR, both in terms of understanding ability and applying skills. Some of these activities include strengthening theories, guiding the development of learning designs, field practices, and guiding conclusions.

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