

11 Prospective

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Prospective Teachers' Understanding and Difficulties in Implementing Research Using Experimental Design

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Abstract: An experimental design is the right choice for education researchers to find out the influence of a factor toward other factors. In practice, some researchers still have difficulties. This study intends to determine the understanding and difficulties of prospective teachers in research activities using experimental design. The researcher used a qualitative descriptive type of research with the sample of the study were the prospective teachers in STKIP PGRI Pacitan who researched using an experimental design in the 2018/2019 academic year. The average researcher examined the effect of learning methods toward student learning outcomes of elementary school, junior high school, and senior high school. Data collection used documentation and interview techniques. Data were analyzed through several stages, and the results showed that prospective teachers had a fairly good understanding of the pre-study and were increasingly understanding at **6** conducting the research process. The researcher experienced initial difficulties in using **statistical methods for analyzing data as well as** difficulties in controlling **the influence of** other factors outside the specified research variables. In the design aspect of the experiment, the researcher assumed that the more factors studied were more complicated so they chose the experimental design with 2-3 factors. Regarding the results of this study, differences in students' initial abilities, such as the level of understanding, intelligence, attention, and response of students need more attention.

Keywords: *understanding, difficulties, experimental design*

INTRODUCTION

Research is a series of scientific activities to solve a problem with the aim of finding explanations and alternative answers or possibilities for solving the problem. The same thing about research is also conveyed by Kuntjojo (2009) that scientific research is a process that is carried out systematically and objectively involving the elements of reasoning and observation to find, verify, and strengthen theories and to solve problems in life. This means that **re**search is conducted to obtain a scientific truth. Research carried out scientifically means **research activities are based on scientific** characteristics, **namely: rational, that scientific inquiry is something that is reasonable and affordable by human reasoning. Empirical,** that research uses **certain methods that can** **5** **observed** by others **using the five human senses**. Systematic, meaning that research uses **a process with certain steps that are logical** (Dharma, 2008).

There are several types of research that are commonly used by researchers in gaining the desired knowledge. One of them is experimental research. However, based on the study of documentation of research studies of mathematics education study program at STKIP PGRI Pacitan by Tisngati et al. (2018) in the 2014-2017 publication year, it was identified that the choice of quantitative research types using factorial experimental methods declined, while qualitative research types dominated. Several reasons were found, namely students had difficulties when conducting experiments because various factors became obstacles, such as limited research time and must give direct treatment to students with certain control efforts. This is as **chara** **13** **istic** of experimental research types

If choosing an experimental study, the researcher manipulates at least one variable, controls other relevant variables, and observes the effect of this **on one or more dependent variables**.

Manipulation of independent variables is one of the characteristics that distinguishes experimental research from other research methods. Sugiyono (2012) explained that experimental research can be interpreted as another research method under controlled conditions. Experimental research aims to determine the comparison and differences in the effects of the treatment of factors or independent variables and interactions between other factors as independent variables on the dependent variable. The aim is to examine the possibility of a causal relationship by applying to one or more experimental groups, one or more treatment conditions and comparing the results with one or more control groups that are not subject to treatment conditions. Treatment conditions can be referred to as factors or independent variables.

There are several alternative variables or factors that can be examined as independent variables and their effects on the dependent variable. In educational research, learning models and learning methods became the independent variables widely studied. The most widely used learning model as an experiment were the cooperative and contextual learning model. Affective factors that can affect a process were also widely studied. Another example of experimental research is research to investigate the effect of two or more methods of teaching certain subjects on students as a function of class size (large and small) and the level of student intelligence (high, medium, low), by placing teachers randomly based on intelligence, size class, and teaching methods.

In general, the characteristics of experimental designs are: (1) demanding strict control of experimental variables and conditions, either by direct control or manipulation or by randomization; (2) typically uses the control group as a baseline to be compared with the experimental group; (3) focusing efforts on controlling variance; (4) internal validity and external validity; (5) in the classical experimental design, all important variables are tried to be constant, except the treatment variables that are intentionally manipulated or allowed to vary; (6) although the experimental method is the most powerful because it makes it possible to control the relevant variables, it is most restrictive and artificial. The main steps in experimental research are: (1) literature study that is relevant to the problem to be solved; (2) identification and defining the problems; (3) formulating a hypothesis based on a literature review; (4) defines the basic notions and main variables; (5) preparing an experimental plan; (6) carrying out experimental work; (7) arranging rough data as a way that facilitates further analysis; (8) conducting significance tests to determine the significance level of the results; (9) arrange an interpretation of the test results, (10) provide a theoretical discussion and write the report.

Beaumont (2009) reported that type of experimental research is a good method for providing learning experiences for students through research activities because this research aims to test the effectiveness of learning theories, look for the presence or absence of intervention or interaction of a variable against other variables in practice in the classroom and educational field, as well as research done to deal with existing problems through testing pedagogical techniques through giving treatment to a group of experimental units. Furthermore, researchers need to have sufficient basic knowledge related to procedures and types of experimental research. Researchers are expected to be able to choose a design that suits the research objectives, including: Pretest Post-Test Control Group Design, Post-Test only Control Group Design, Solomon Four-Group Design, Factorial Design, Some factors to Consider.

Kirk (1995) explained that an experimental design is a plan for assigning experimental units to the level of treatment and statistical analysis associated with the plan. Factorial design is one of the experimental research designs that researchers can use to test the effect of several experimental units on other experimental units. Statistical analysis uses variance analysis which

is used to explain two or more treatments. The treatment variable is symbolized by and so on according to the number of factors to be studied. In general, experimental research with factorial design has the objective to test or investigate the effects of several factors as independent variables, individually or together (interaction) on the dependent variable in which each factor has at least two levels that can be combined in the form of experimental design. Trochim (2006) explained that there are several advantages to applying factorial experimental research, including: (1) flexibility to investigate treatments in the study, (2) efficient, because it can make several combinations, (3) effective ways to test the effects of interactions.

Mattjik and Sumertajaya (2000) explained that the type of experimental research with n factor design is an experiment or series of experiments using both statistical description and statistical inference, which aims to convert input into an output that is the response of the experiment. Treatment design is a design related to how the treatments are formed with the composition of the treatment can be one factor, two factors, three factors, and so on. As an example of 2 factors factorial design, there are two factors (A and B), where A has 3 levels (a) and factor B has 3 levels (b), a designation of a partial $a \times b$ or 3×3 combination treatment can be determined. Factorial design 3 factors with A, B, and C, where there are a factor A has 3 levels (a), factor B has 2 levels (b), and factor C has 2 levels (c), it can be determined a factorial experimental design designation of $a \times b \times c$ or $3 \times 2 \times 2$ treatment combinations. Previous studies by Tisngati et al. (2019), done a factorial design 4 factors in experimental research in which experiments of 4 main factors as independent variables to the dependent variable. That is, there are 4 factors that can be the cause or effect of changes in the dependent variable.

Based on the description above, one of the experimental studies with factorial design should be a good method to be applied for example research in the social, scientific, and technical fields. Steinberg & Hunter (1984) stated that students and teachers need to explore new things through experimental design. For example, researchers can investigate the effectiveness of factors that can influence the results of activities in education and agriculture. In the field of science, Hanrahan and Lu (2006) explained that factorial design as a method in experimental research has been carried out in the biological, environmental and pharmaceutical fields, food technology and related industry processes examined. Others, Politis et al. (2017) reported that among various mathematical modeling approaches, Experimental Design (DoE) was widely used for the implementation of Quality by Design (QbD) and modern engineering-based manufacturing methodologies, both in research and industrial settings. In experimental research, there are many variables that can be controlled so that it affects other variables, conversely in the same situation there are several factors that influence the results of research without being able to be manipulated before. However, as in previous research findings that there are several factors that are the reason so some researchers choose the type of non-experimental research. Thus this study aims to determine the understanding and difficulties of prospective teachers in research activities using experimental designs.

METHOD

Types of research

In accordance with the objectives of the research carried out, this research is classified as a qualitative descriptive study because in this study will describe the situation that is happening now systematically and factually with the aim to describe and resolve the problem to be studied. According to Moleong (2014), qualitative research is research intended to understand phenomena about what is experienced by research subjects, for example, behavior, perception,

motivation, and action, holistically and by means of descriptions in the form of words and language, in a particular context which is natural and by utilizing various methods. Sugiyono, (2012) explained that description of the theory in a study is a systematic description of the theory (not just the opinions of experts or authors of books) and research results that are relevant to the variables studied. Describe means to explain about a situation or social situation under study so that the phenomenon that occurs becomes clearer. The social situation to be investigated is the understanding and difficulty of prospective teachers in research activities using experimental designs.

Research subject

In general, the subject in a study is identical to the population to be studied. According to Spradley, cited by Sugiyono (2012), qualitative research does not use the term population but rather as a social situation consisting of three parts: place, actors, and activities that interact synergistically. The subjects in this study were 8 final semester students or prospective teachers from 2 study programs at STKIP PGRI Pacitan in the even semester of the 2018/2019 academic year. Each study program was taken 4 students who used quantitative research types, namely 2 students with the experimental method and 2 students with the non-experimental method. The selection of research subjects was based on the consideration that students already had sufficient learning experience in the form of research as a final project. It was expected that the subject can provide information in accordance with the objectives of the study in order to obtain accurate data needed in this study. Determination of the subject in this study using a purposive sampling technique. Sugiyono (2012) explained that purposive sampling is a technique for taking data sources with certain considerations

Data collection

Based on the data used, the data collection techniques used in this study were documentation and interviews. The documentation was a report of research results from 8 students of prospective teachers. The interview guide used was a semi-structured interview in which the researcher designs guidelines for interview steps that can be developed based on the situation and condition of the research subject. This interview technique is the main data collection technique because the interview is one form of data collection techniques that are carried out orally in face-to-face meetings individually. Interviews were conducted to 8 students of the prospective teachers as research subjects. The questions related to indicators of understanding and difficulties of prospective teachers in research activities using experimental designs.

Basuki (2014) explained that understanding means understanding meaning, translation, making interpolation and interpreting learning and can express problems with their own language. It means understanding is not just about remembering facts but with regard to the ability to explain, explain, interpret, or the ability to express the meaning or meaning of a concept. Related to this research, indicators of comprehension ability are the ability to translate, interpret or extrapolate and explain capabilities related to experimental research. This is realized from the stage of understanding and being able to carry out the procedures of planning, implementing, analyzing data, preparing reports to disseminating research results. The results of the interview will divide the subject into 5 categories of understanding, namely: A: 9-10, Excellent (E); B: 8-9, Very Good; C: 7-8, Average; D: 6-7, Below Average; F: 0-6, Failing. Furthermore, indicators of difficulty include clarity, accuracy, relevant, consistent, logical, and completeness.

Validity and data analysis techniques

The findings or research data are declared valid if there was no difference between what the researcher reports and what actually happened to the object of study. The validity of the data in this study was based on a criterion, namely the credibility test. Sugiyono (2012) explained that data credibility test or trust in qualitative research data was carried out with extended observations, increased perseverance in research, triangulation, negative case analysis, using reference materials and holding member checks. As a test of credibility, researchers used documentation and interview techniques to confirm data from the same source and confirm data from different sources with the same technique. Another credibility test was that researchers used reference material to increase trust in the results of this study. The data analysis technique used was descriptive narrative using the model of Miles and Huberman as cited by Sugiyono (2012) in which qualitative data analysis is conducted interactively and continues continuously until it is complete so that the data is saturated. At the time of the interview, researchers have done an analysis of the answers interviewed. If the answers interviewed after being analyzed are not satisfactory, then the researcher will continue the question again, to a certain extent, obtained data that is considered credible.

RESULTS AND DISCUSSION

Results

The results of this study were obtained from interview techniques on 8 research subjects, namely students as prospective teachers from the mathematics education study program (4 subjects) and prospective teachers from the elementary school teacher education study program (4 subjects) who had taken the final project in the form of research. Subjects that were given research questions were experimental group types of researchers, consisting of Ri (S1), Af (S2), Wi (S3), Si (S4) and non-experimental types, consisting of: Re (S5), Tr (S6), Pu (S7), He (S8). The following presents the interview data made in tabular form.

Table 1. Understanding of prospective teachers about experimental research (experimental research groups)

Skills	S ₁	S ₂	S ₃	S ₄
Ability to explain	the subject could explain the characteristics of experimental research (B)	B	B	B
The ability to interpret	✓ Subjects could distinguish the characteristics of experimental research with non-experimental (B)	B	B	B
	✓ Subjects could prepare experimental research procedures (B)	B	B	B
	✓ Subjects could carry out experimental research according to procedure (B)	B	B	B
	✓ Subjects could present experimental research data (B)	C	C	B
the ability to express meaning	✓ The subject could answer the research hypothesis (B)	B	B	B
	✓ Subjects could use theory to discuss experimental research results (B)	C	C	B

Notes: category: A: Excellent; B: Very Good; C: Average; D: Below Average; F: Failing

Table 2. Understanding of teacher candidates about experimental research (non-experimental research groups)

Skills	S ₅	S ₆	S ₇	S ₈
Ability to explain	The subject could explain the characteristics of experimental research (B)	C	C	B
2 The ability to interpret	<ul style="list-style-type: none"> ✓ Subjects could distinguish the characteristics of experimental research with non-experimental (B) ✓ Subjects could prepare experimental research procedures (B) ✓ Subjects could carry out experimental research according to procedure (C) ✓ Subjects could present experimental research data (B) 	B	B	B
the ability to express meaning	<ul style="list-style-type: none"> ✓ The subject could answer the research hypothesis (B) ✓ Subjects could use theory to discuss experimental research results (C) 	11 B	B	B

Notes: category: A: Excellent; B: Very Good; C: Average; D: Below Average; F: Failing

Based on data from the understanding of prospective teachers about in research activities using experimental design, it was continued with a search of the difficulties of prospective teachers in using experimental research designs focused on researchers who choose the type of experiment. Data were taken and summarized from the research documents followed by confirmation by interview. Here is the data.

Table 3. Difficulties of prospective teachers about experimental research (experimental research groups)

Aspect	S ₁	S ₂	S ₃	S ₄
clarity	Difficulties in the part of research methods and statistical tests if they involve many variables	Difficulties in the statistical test section	Trouble choosing a sampling unit	Difficulty in compiling research instruments if adapted to different types of problems
accuracy,	Difficulty in getting real data, Difficulty in planning data analysis steps	Difficulty in getting data in accordance with the objectives of the study	Difficulty in getting optimal data due to limited research time	Difficulty in getting valid data because the sample was not really ready
relevant,	Difficulty in getting the first, most recent, and appropriate reference source	Difficulty in determining data analysis techniques due to many variations	Difficulty reading results from statistical data calculations	Difficulty in getting primary reference sources
consistent,	Have no trouble	Difficulties in writing statistical test formulas using equations	Difficulty in discussing coherent due to weaknesses of written language	Difficulty in using mathematical formulas and symbols consistently
logical,	Difficulty in using grammar in composing sentences	Difficulty in using grammar in composing sentences	Difficulty in using language in composing sentences	Difficulty in using grammar in composing sentences
completeness	The discussion was quite detailed but easy to understand.	The discussion was quite detailed but easy to understand	The discussion was quite detailed but easy to understand	The discussion was quite detailed but easy to understand

Conversely, the reasons for prospective teachers not to choose the type of research with an experimental design were explored based on the interviews. Here is the data.

Table 4. Difficulties of prospective teachers about experimental research (non-experimental research groups)

Aspect	S ₅	S ₆	S ₇	S ₈
Difficulty Types	<ul style="list-style-type: none"> ✓ difficulties in this part of the research process, must teach ✓ statistic test ✓ lack of mastery of experimental research methods 	<ul style="list-style-type: none"> ✓ difficulty managing research time ✓ difficulty in doing many tests 	<ul style="list-style-type: none"> ✓ difficulties in learning practice because it required a long time ✓ less mastered experimental research methods 	<ul style="list-style-type: none"> ✓ difficulty in compiling research instruments for teaching ✓ difficulty of statistical tests

Discussion

Based on the explanation in the table above, it can be seen that each group shows no different data or generally shows the same tendency from different sources.

Understanding aspects

Based on table 1 and table 2, conclusions can be presented as shown in Table 5.

Table 5. Summary of prospective teacher understanding data about experimental research (experimental research group)

Skills	S ₁	S ₂	S ₃	S ₄	Conclusion
Ability to explain	B	B	B	B	B
The ability to interpret	B	B	B	B	B
The ability to express meaning	B/C	B/C	B/C	B/C	B/C

Notes: category: B: Very Good; C: Average

Table 6. Summary of data prospective teacher understanding of experimental research (non-experimental research groups)

Skills	S ₁	S ₂	S ₃	S ₄	Conclusion
Ability to explain	C	C	C	C	C
The ability to interpret	C	C	C	C	C
The ability to express meaning	B/C	B/C	B/C	B/C	B/C

Notes: category: B: Very Good; C: Average

Prospective teachers with experimental research groups have the ability to explain and interpret in the very good (B) category, while the ability to express meaning between very good (B) and average (C). This data differs from the non-experimental research group in which the ability to explain and interpret in the average (C) category, while the ability to express meaning between very good (B) and average (C), is the same as the experimental research group.

Difficulty aspects

Based on previous exposure, each group of researchers showed difficulties in selecting and applying experimental designs to research activities. Watson et al. (2019) reported that there are many reasons for erroneous and bias results invalidity of scientific research in the fields of psychology and medicine. This is in accordance with Beaumont (2009), because there are many variations of experimental designs. In the experimental research group, the data shows, namely: in the aspect of clarity, difficulties in the research methods and statistical tests, especially if it involves a lot of variables. In the aspect of accuracy, the difficulties in the process of getting

valid data are because the sample was not really ready to be investigated or difficult to control, also because of the limited time of the study. In the relevant aspect, the difficulties were in getting the first, most recent, and appropriate reference sources, as well as choosing the most appropriate statistical test equipment. In the consistent aspect, the difficulty in writing statistical test formulas was using equations as well as symbols and formulas. In the logical aspect, the difficulty of prospective teachers was in the use of grammar in preparing sentences. In terms of completeness, the average discussion lacks detail, but this was easily understood.

The types of difficulties experienced by prospective teachers who choose the type of non-experimental research were in part: (1) research methods, including lack of understanding of research procedures, research design, sampling, instrument preparation, instrument testing, validity testing, statistical tests; (2) the difficulty of having to practice teaching; and (3) limited research time so it is considered less than optimal if you have to choose experiments.

In general, the difficulty of researchers applying experimental design was the use of statistical tests, according to the characteristics of experimental research, Kirk (1995). In other words, as Sadaghiani and Bao (2006) reported that students have difficulty in interpreting the quantitative outcomes for these terms into physical meaning. In the more important part is, if researchers do not understand correctly the use of theory, including the existence of internal and external validity requirements in the design of an experiment, there will be biased research results. As Campbell & Stanley (1963) wrote about 12 factors that jeopardize internal and external validity. In addition there are 8 foreign variables that can affect research results if they are unable to be controlled by researchers in the experimental design, namely: history, maturation, testing, instrumentation, statistical regression, experimental mortality, selection of respondents, selection-maturation interaction. Referring to the results of this study, the authors note that there are advantages for researchers who use experimental research, that is, researchers can control unwanted or alien variables. Second, it is easy to determine cause and effect relationships by manipulating independent variables or treating variables. Regarding the results of this study, differences in students' initial abilities, such as the level of understanding, intelligence, attention, and response of students need more attention.

Based on the fact, adapting from Sears and Schwartz† (2007) reported that collaborative learning has been successful at promoting student achievement. This method is an alternative to reduce the difficulty of prospective teachers in learning research by experimental design. Adopted by the findings of the study of Pimthong and William (2018), suggest the importance of promoting prospective teachers' understanding of the integrated nature of research main characteristics and the connections among the learning theory. The prospective teacher found the variety of difficulty in experimental research, as a practical implication, lecturers on research methodology need to apply group research or pairs working.

CONCLUSION

Kilkenny et al. (2009) explained that the appropriate and efficient experimental design is a critical component of high-quality science. According to the the study result, it shows that the consideration of researchers (in this case prospective teachers) determining the type of research influenced by their understanding of the research method. Indicators relate to the ability to explain, the ability to interpret, and the ability to express meaning. This is consistent with the results of this study which show that the experimental research group was in the very good category, with indicators: can distinguish differences in the characteristics of experimental design research compared to other types of research, can plan steps, prepare instruments, carry

out research procedures to analyze data, discussion using relevant theory and previous research, and determining conclusions. Nevertheless, researchers have difficulties in practice using experimental designs. The types of difficulties experienced by prospective teachers who choose the type of experimental design research are in part: (1) research methods, including lack of understanding of research procedures, research designs, sampling, instrument preparation, instrument testing, validity testing, statistical tests; (2) difficulties in using grammar and reference sources; and (3) lack of deepening in the aspects of the discussion using theory.

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