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Application of Problem-based Learning Based Set Mobile Game Oriented to Motivation, Interest, and Logical-Mathematical Thinking

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ABSTRACT

The purpose of this study is to describe (1) the effectiveness of problem-based learning using Mobile Games; (2) the effectiveness of conventional learning using Mobile Games; and (3) the comparative effectiveness between problem-based learning using Mobile Games and conventional learning using Mobile Games in terms of students' motivation, interest, and logical-mathematical thinking ability. This research is a quasi-experimental study with a population of all seventh-grade students at SMP Negeri 1 Minggir, and the sample comprises classes VIIF and VIIG, each with 31 students. Data were obtained using non-test and test instruments. The effectiveness of mobile game treatment in each class was analyzed using t-tests and MANOVA (Hotteling T^2). The results of this study show: (1) problem-based learning using Mobile Games is effective in terms of students' motivation, interest, and logical-mathematical thinking ability based on questionnaire and post-test; (2) conventional learning using Mobile Games is effective in terms of students' motivation, interest, and logical-mathematical thinking ability based on questionnaire and post-test; and (3) the results of the comparative effectiveness analysis show that problem-based learning using Mobile Games is more effective compared to conventional learning using Mobile Games in terms of students' motivation, interest, and logical-mathematical thinking.

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1. INTRODUCTION

Learning and motivation are interrelated processes. The behavior of learning new knowledge cannot be carried out unless motivated to do so [1]. Motivated individuals consider a valuable activity for the future and realize that a skill can be developed through that activity. Adamma et al. [2] observed that both intrinsic and extrinsic motivation contribute to improving student academic achievement. Ryan and Deci [3] stated that intrinsic motivation relates to activities carried out "for the individual's own benefit," while extrinsic motivation encourages individuals to engage in activities for external reasons. Learning motivation refers to an individual's involvement in beginning to learn or in actively engaging in learning [4].

Factors that influence learning motivation according to Kılıç et al. [5] are: 1) sociocultural factors; 2) classroom environmental factors, and 3) internal factors. Meanwhile, according to Tin [6], factors that influence learning motivation include 1) learning and teaching factors; 2) factors during learning; 3) evaluation factors; 4) environmental and material factors. Learning motivation factors are used to increase individual effectiveness and efficiency.

The motivation to participate in a learning activity begins with an interest in the activity. Ainley [7] states that deliberate involvement in an activity with positive feelings is called interest in learning. Ainley et al. (2002), cited in Putra and Setyaningrum [8], divided learning interest into three types: individual interest (originating within the individual and relatively stable); situational interest (influenced by specific environmental factors); and topic interest (related to a particular topic or subject). Learning interest influences student performance in learning [9]. Xu [10] investigated and found that students' learning interest is influenced by teacher feedback quality, classroom management, self-concept, assignment quality, and learning objectives.

Teachers' low competence in mastering scientific thinking patterns results in low student motivation and interest in learning [11]. Class time allocation that does not provide opportunities for students with low understanding further reduces motivation and interest in learning [12]. Arum et al. [13] state that, in addition to motivation and interest in learning, which influence students' mathematics learning achievement, intelligence categories should also be considered to support and facilitate the success of the learning process in class.

In the 2022 Program for International Student Assessment (PISA) in mathematics, Indonesia obtained 366 points (with an average of 358) [14]. In 2018, Indonesia obtained 379 points (with an average of 489 points) [15], down 7 points from the 2015 PISA results, which obtained 386 points (with an average of 490 points) [16]. The decline in scores and PISA results in 2015 and 2018, which are still below average, indicates that Indonesian students' mathematical abilities remain low. Only 29% of Indonesian students (with an average of 76%) achieved level two or higher proficiency where students can interpret and recognize without direct guidance and represent simple situations mathematically and 1% of students (with an average of 11%) scored at level five or higher where students can create mathematical models of complex situations, choose, compare, and evaluate appropriate problem-solving strategies in solving mathematical problems [17].

The abstract nature of objects in mathematics learning makes it difficult for students to understand concepts and reduces students' interest in learning activities at the next level [4]. Nurlaily [18] stated that students who tend to memorize formulas and who experience an unsupportive learning climate often have difficulty developing problem-solving skills. Mathematics instruction that forces students to memorize formulas and definitions without interpreting them decreases students' interest in learning [19]. One of the mathematics materials at the junior high school level is sets [20]. Sets are a prerequisite for studying probability [21]. The material on probability and the relative frequency of an event applied to a simple experiment is included in the minimum criteria for the scope of material at the junior high school level.

Gardner [22], as cited in Tan [23], defines intelligence as the ability to solve problems in real-world contexts through various ways of thinking. Gardner [24], in Putri and Widjajanti [25], views intelligence as the ability to create works that have cultural value. One of the multiple intelligences that plays a role in mathematics learning is logical-mathematical intelligence. Logical-mathematical intelligence is the ability to “processing” knowledge and skills that involve logical-mathematical thinking.

Muzaky et al. [26] state that logical thinking is the ability to think coherently based on facts. The stages of logical thinking include analogy, generalization, and direct proof [27]. Mathematical thinking, according to Schoenfeld [28] in Miswanto et al. [29], is the process of developing a mathematical point of view. The stages of mathematical thinking include abstraction, modeling, reasoning, proof, symbolization, representation, and mathematization [30]. Logical-mathematical thinking is the activity of processing knowledge by seeking logical patterns and relationships, making assumptions, and drawing logical conclusions.

Individuals with good logical-mathematical intelligence find it easier to understand and solve problems. Meanwhile, students with low logical-mathematical intelligence find it more difficult to understand and solve problems [31]. Fatimah et al. [32] concluded that low logical-mathematical thinking skills, which influence low problem-solving abilities, can be overcome through meaningful learning by presenting real-life problems.

The use of real-life problems in learning mathematics material aligns with the characteristics of problem-based learning, which uses problems as a starting point for learning [33]. Constructivist learning theory, which emphasizes that students investigate the environment and build meaningful knowledge independently, provides the theoretical basis for problem-based learning [34]. Ardeniyansah and Rosnawati [35] state that student-centered learning involving everyday life problems can stimulate students to learn more actively by finding solutions to these problems in discussion groups. Real-life problems used in learning can attract students' interest in learning [4], motivate learning [36], and support student learning completion [37]. Student creativity can also be increased through problem-based learning by seeking various solutions during the problem-solving process [38].

Moust et al. [39] state that, in problem-based learning, in small collaborative groups, students are presented with unstructured everyday life problems as a starting point for the learning process, discussing the problems under teacher guidance, tentatively analyzing the problems based on relevant knowledge, reporting the results of the discussion and evaluating the achievement of understanding of the problem through independent learning. By working on unstructured problems, students are cultivated to use various realities, perspectives, and philosophical views rather than a single answer.

Difficulty in determining relevant problems: students are not used to receiving problems without direction, and limited time allocation for each activity. Problem-based

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learning becomes an obstacle that teachers find in the classroom [18]. The limited time allocation must be managed for activities such as organizing students, guiding groups, and providing feedback on problem-solving, which is less explored. The integration of mathematical material with various types of game-based questions helps students understand the material with limited allocation [19]. Damrongpanit [40] observed that not only can the use of teaching methods influence learning achievement, but other factors, including non-academic factors within students, can also influence it.

Educational success is inseparable from the learning process, which includes several interrelated components [41]. These components include teachers, students, objectives, learning materials, media (equipment/facilities), methods or patterns of delivery, and evaluation of learning. Learning media, as part of the components of the learning process, are indirectly affected by increasingly advanced technology, including mobile devices.

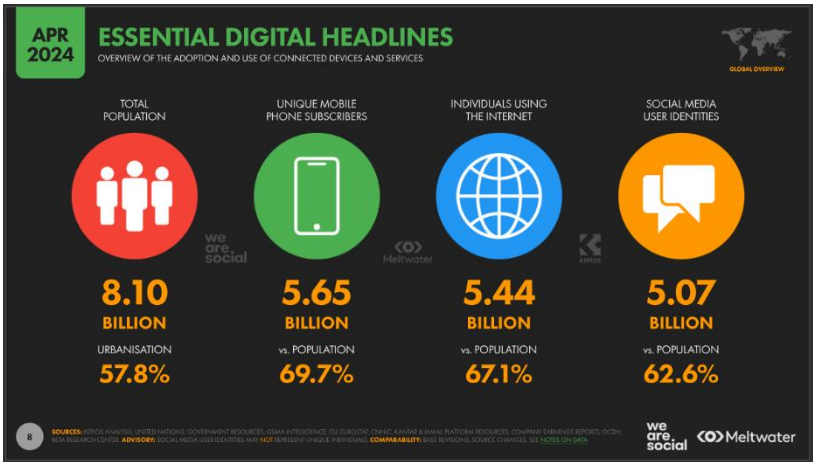

Figure 1. Mobile device users as of April 2024 (Digital, 2024)

Attractive touchscreen interactions and directly accessible interactive applications are a unique strength in creating opportunities and developing mobile devices for many education and training programs. The *mobile device includes: a personal digital assistant (PDA), a mobile phone with SMS, a smartphone, a tablet, a game console, an iPod*, and wireless infrastructure [42], [43]. Data Report 2024 [44] shows that mobile device users as of April reached 69.7% (5.65 billion of the total population), and 11.5% used mobile devices for *games.*

Applications in the form of games on mobile devices, adapted to the appropriate delivery pattern, can serve as an efficient learning medium and be used at school or at home [45]. Bilgin [46] found that a *game* directed towards learning objectives can make a positive contribution to students' attitudes and learning motivation and can help control students' anxiety during learning. *Game* for learning to facilitate students in problem solving in students with heterogeneous comprehension abilities [47].

Usefulness in learning is not supported by teacher enthusiasm for its use. Russo [48] stated that limited technical experience reduces teachers' interest in developing and implementing games for learning. Diverse perceptions of the use of *learning games* have sparked controversy among students, teachers, and parents. The perception tends to be negative among teachers and parents, due to ignorance of the distinction between *game* entertainment and *game* learning [49]. Other challenges, according to Laato et al. [50] and Xie et al. [49], include the availability of game quality for curricular purposes remaining limited. Design*game* still prioritizes entertainment over learning. The combination of mobile devices and the game application that accompanies them in the learning environment needs to be considered in terms of strategic design and pedagogical practices.

Integration of mathematical material with various types of game-based questions can help students understand the material, thereby increasing their interest or passion for learning [19]. The use of games in learning fosters situational interest, which, in turn, will influence the growth of relatively stable individual interest [12]. *Game* design must consider core competencies and basic competencies related to the mathematics material to be integrated. Using a learning approach can also make it easier for teachers to explain and develop teaching materials tailored to learning objectives.

Presenting lesson material in a limited environment, such as a game, does not necessarily require the use of a particular learning approach. The presentation of the set material will be packaged as a mobile learning gam*e*. Obstacles or barriers in *the game, which were previously designed only for entertainment, will be transformed into everyday life problems to create meaningful learning that* can ultimately maximize learning objectives. *The game "Proadventure," developed [45] using the guided inquiry learning method in probability material, shows that acceptance of th*e *game* among teachers and prospective teachers in mathematics learning is quite high. However, students were hesitant to use games in learning and lacked confidence when learning without a teacher. Fahuzan and Santosa [33] developed the game "The Story of Kuncung: An Extraordinary Adventure in Learning Arithmetic," which uses problem-based learning in social arithmetic material that utilizes narrative flow, making it easier for students to learn mathematics. However, in this type of *adventure game, the results indicate* that female students' learning motivation tends to be low.

The sophistication of mobile devices attracts researchers' interest in designing and implementing problem-based learning games that utilize everyday life problems related to the set at the start of each game. *Game*-based *problem-based learning* on mobile devices by presenting real problems will make learning more meaningful. The meaningfulness of learning and *fun games is used to support students' heterogeneous abilitie*s in building learning motivation [33]. The allocation is controlled by a *game* designed for learning activities, which helps students with low levels of knowledge grasp learning material both inside and outside the classroom. Solving unstructured everyday-life problems also requires strong logical-mathematical thinking skills. The game includes challenges and problem-solving strategies to help students practice logical-mathematical thinking skills.

Based on the above explanation, the researcher intends to conduct research titled "Implementation of *Mobile Game* Based Set *Problem-based Learning* Oriented towards Motivation, Interest, and Logical-Mathematical Thinking".

2. METHOD

This research is an experimental study. Experimental research is defined as research in which researchers test whether a treatment affects one group differently from another [51]. The quantitative research design used is a quasi-experimental *(quasi-experiment).* In the quasi-experimental design, researchers use intact groups that have already been formed and do not artificially create classes [51]. The quasi-experimental design used in this study is a *pre- and post-test design*. Researchers used a pretest to "equalize" class characteristics before treatment, and a *posttest* was conducted to measure changes in characteristics after treatment [51]. The pre- and posttest research design used in this research is presented in Table 1 below.

Table 1. Research design

Class	*Pretest*	Treatment	*Posttest*
Experiment 1	THE1	Xe1	THE2
Experiment 2	THE3	Xe2	THE4

Information:
O_1 : Pretest of experimental class 1
O_2 : Posttest of experimental class 1
O_3 : Pretest of experimental class 2
O_4 : Posttest experimental class 2
X_{e1} : Learning using a *mobile game*-based *problem-based learning* for set material
X_{e2} : Learning using a *mobile game* based on conventional learning for set material

Looking at Table 1, this study uses two treatments: mobile game-based problem-based learning and mobile game-based conventional learning. Before treatment, each group was given a pretest to measure motivation, interest in learning, and logical-mathematical thinking skills. After that, *the pretest is given good treatment by using a mobile game-based problem-based learning or a mobile game-based conventional learning for the set material, and at the end of each class, a posttest is given*.

3. RESULTS AND DISCUSSION

3.1. Results

Effectiveness test, *mobile game,* carried out in each class, against post-test logical-mathematical thinking, final motivation score, and final score of student learning interest. Analysis using *test value* 12.25 for *post-test* students' logical-mathematical thinking, *test value*42 for motivation score, and *test value* 49 for student learning interest scores. The following describes the results of the hypothesis test for each experimental class.

***Mobile Game-Based Problem-Based Learning*:** Class effectiveness. Mobile game-based problem-based learning viewed from the perspectives of mathematical logical thinking, students' motivation, and interest in learning can be identified by analyzing scores: post-test logical-mathematical thinking, final scores of students' motivation, and interest in learning using a *one-sample t-test.* A one-sample t-test using SPSS 26 is presented in Table 2.

Table 2. Results of the One-Sample t-test for the Problem-based Learning Mobile Game Class

Variables	t	Sig. (2-tailed)
Logical-mathematical thinking	25.449	0.000
Motivation to learn	10.875	0.000
Interest in learning	11.918	0.000

Based on Table 2, it can be seen that the significance value of the test*one sample t-test is* less than alpha(a), that is (0,05) for the variables of logical-mathematical thinking, motivation, and interest in learning students in the class *Mobile game*-based *problem-based learning.* Based on the criteria for concluding, H0 is rejected, so it can be concluded that the class-based mobile game problem-based learning is effective in improving students' logical-mathematical thinking skills, motivation, and interest in learning.

Class *Mobile Game*-Based Conventional Learning: Effectiveness. Mobile game-based conventional learning, viewed from the perspective of logical-mathematical thinking, allows students' motivation and interest in learning to be identified by analyzing post-test logical-mathematical thinking scores and final scores of students' motivation and interest in learning using a *one-sample t-test.* A one-sample t-test using SPSS 26 is presented in Table 3.

Table 3. Results of the One-Sample t-test for Mobile Game Classes Based on Conventional Learning

Variables	t	Sig. (2-tailed)
Logical-mathematical thinking	18.409	0.000
Motivation to learn	5.609	0.000
Interest in learning	7.747	0.000

Based on Table 3, it can be seen that the significance value of the test, *the one-sample t-test, is less than alpha (a) (0,05) for the variables of logical-mathematical thinking, motivation, and interest in learning for* students in the class *mobile game* based on conventional learning. Based on the criteria for concluding, then H0 is rejected, so it can be concluded that the mobile game class based on conventional learning is effective in improving students' logical-mathematical thinking skills, motivation, and interest in learning.

Results of the Comparison Test of Effectiveness *of the Mobile Game: The effectiveness difference test was conducted on data collected before and after treatment for the class mobile game based on problem-based learning and the* class *mobile game* based on conventional learning. The comparative test of data before treatment aims to determine whether there is a difference in initial abilities between the two classes before treatment is given. If the initial abilities of the two classes are the same, then the comparative test of effectiveness *in the mobile game uses the post-treatment score to determine which mobile game is more effective in improving students' logical-*

mathematical thinking skills, motivation, and interest in learning. Comparative analysis of the effectiveness of scores before and after treatment using the MANOVA test with the help of *software* SPSS *Statistics* 26. Results of the comparative analysis of the effectiveness of mobile game-based problem-based learning and a mobile game based on conventional learning are shown in Table 4.

Table 4. MANOVA Test Results for Data Before Treatment

Before Treatment	F	Say.
Hotteling's Trace	1.984	0.126

Based on the MANOVA test in Table 4, it can be seen that the significance value is more than (0.05) so that H0 is accepted. Therefore, it can be concluded that there is no difference in the average initial abilities of the two classes in terms of logical-mathematical thinking, student motivation, and interest in learning. The results of the comparison test of the mobile game's effectiveness after treatment are shown in Table 5.

Table 5. MANOVA Test Results for Data After Treatment

Before Treatment	F	Say.
Hotteling's Trace	14.503	0.000

Based on the output results *software* SPSS *Statistic* 26 in Table 5, it can be seen that the significance value is less than alpha (a), that is (0,05) so that H0 is rejected. This shows that there is a difference in the average final abilities of students in the two experimental classes in terms of logical-mathematical thinking, motivation, and student learning interest. Therefore, further testing is needed to determine which *mobile game* is more effective for each variable tested.

3.2. Discussion

Effectiveness of *Mobile Game-Based Problem-Based Learning* reviewed from the perspective of Learning Motivation, Learning Interest, and Logical-Mathematical Thinking Ability.

Implementation of learning during treatment in the classroom*, mobile game-based problem-based learning, was observed to determine the extent to which* the implementation is effective in the *mobile game* that has been designed. Based on the observations, the implementation of classroom learning, mobile game-based *problem-based learning* is 100% for teachers and 100% for student activities. The implementation of learning shows that learning activities are student-centered. The use of problem-based learning methods and approaches that involve students in *games* encourages active involvement in the learning process [52].

Effectiveness testing *of mobile games on students' motivation and interest in learning is based on the final scores for motivation and interest in learning, while the test of the effectiveness of logical-mathematical thinking ability is based on the post-test results.* Based on the analysis of the final scores for learning motivation, learning interest, and post-test logical-mathematical thinking ability, the results indicated that mobile game-based *problem-based learning* was effective in increasing learning motivation, interest in learning, and logical-mathematical thinking skills.

The selection of appropriate learning approaches and methods between the material and the media used must be considered. Presentation of material using *mobile games* with learning methods and approaches; problem-based learning influences students' motivation and interest in learning and improves learning achievement [53]. Learning activities that are engaging and visually appealing encourage student involvement. Moust et al. [39] state that *problem-based learning* uses everyday life problems as a starting point for the learning process. This encourages students to think rationally in learning mathematics. Involving *games* in learning helps students in transferring knowledge to real life [54].

In addition, the use of *Mobile* in mathematics learning improves high-level skills (HOT) abilities and learning motivation, and is effective, efficient, and interactive [55]. Mathematics learning using *a game encourages students to use problem-solving, reasoning, proving, and transfer skills* [56]. Sun et al. [57] found that, *in mathematics learning, achievement can be improved, including problem-solving skills,* algebra, geometry, reasoning, arithmetic, and critical thinking. Based on this, it is proven that *mobile game*-based *problem-based learning is effective.* The set can improve students' logical-mathematical thinking skills, motivation, and interest in learning.

Effectiveness of *Mobile Game* Based on Conventional Learning reviewed from the perspective of Learning Motivation, Learning Interest, and Logical-Mathematical Thinking Ability

Learning during treatment in the classroom and a mobile game based on conventional learning have been observed, so it can be determined to what extent the mobile game has been designed. Based on the results of the observations, the implementation of classroom learning mobile games based on conventional learning increased the teacher's activity level to 100% and the students' activity level to 90.7%. Meanwhile, when viewed individually, there was a general trend of improvement from the first to the third meeting. In terms of teacher learning implementation, the first to third meetings achieved 100%. Furthermore, in terms of student activity, the first meeting achieved 72%, and the second to third meetings achieved 100%. *Game-based mathematics instruction* can overcome disinterest and encourage student involvement in learning [58].

Effectiveness testing *of mobile games on students' motivation and interest in learning is based on the final scores for motivation and interest in learning, while the test of the effectiveness of logical-mathematical thinking ability is based on the post-test results.* Based on the analysis of final scores for learning motivation, learning interest, and post-test logical-mathematical thinking ability, the results indicated that mobile games based on conventional learning were effective in increasing learning motivation, learning interest, and logical-mathematical thinking skills.

In mathematics learning, it facilitates students' connections with one another in competitions, thereby fostering a spirit of learning that positively influences motivation and interest in learning [59]. Presenting interesting material in the form of games is appealing because of the element of challenge, which can positively enhance student involvement in learning. The transfer of knowledge that occurs in *games* can improve students' mathematical problem-solving abilities [60]. Based on this, it is proven that *mobile games* based on conventional learning can improve students' logical-mathematical thinking skills, motivation, and interest in learning.

Comparison of the Effectiveness of *Mobile Game-Based Problem-Based Learning* and *Mobile Game* Conventional Learning Based on Learning Motivation, Learning Interest, and Logical-Mathematical Thinking

Comparison of effectiveness between class-based problem-based learning and class-based mobile game-based learning, using conventional learning, to determine which mobile game is more effective in increasing students' learning motivation, learning interest, and logical-mathematical thinking. This test was conducted on the final scores of learning motivation, learning interest, and *post-test* students' logical-mathematical thinking abilities. Based on the multivariate mean vector similarity test of the final scores for learning motivation, learning interest, and post-test logical-mathematical thinking ability, the results showed a difference in the average vector between the two experimental classes. Therefore, further testing was carried out to identify a mobile game that is more effective at increasing students' learning motivation, interest in learning, and logical-mathematical thinking skills. After further testing, namely *independent-samples t-tests on the post-treatment data, the results indicated that mobile game-based problem-based learning was more effective than mobile game-based conventional learning, as assessed from students' learning motivation, learning interest,* and logical-mathematical thinking abilities.

If we look at the final scores for students' learning motivation and learning interest, there are differences of 6.0645 and 8.2903, respectively, while post-test logical-mathematical thinking ability shows a difference of 1.4193. This difference shows that the final scores for students' learning motivation, learning interest, and post-test logical-mathematical thinking skills in the class mobile game-based problem-based learning are higher than those in the class mobile game-based conventional learning. Class effectiveness *of a mobile game-based problem-based learning, according to the opinion of Munawaroh et al. [53], states that the use of problem-based learning in mathematics learning in the form of game-based* student-centered learning and discussion. This statement reinforces the importance of selecting problem-based learning approaches and methods *that appropriately* connect the lesson material with the *game.*

The subject matter presented in *the game provides* direct feedback [61], allows students to try tasks multiple times [62], allows students to explore [63], and is interactive [64]. The presence of challenges in game-based learning motivates and interests students to learn in new ways [57]. Although *games* have a positive impact, there are challenges, namely integrating lesson materials into games using conventional methods and approach*es* [65]. Teacher-centered learning limits students' ability to explore learning. This statement reinforces the analysis that *mobile game*-based *problem-based learning is more* effective than *mobile game-based* conventional learning.

4. CONCLUSION

Based on the results of the data analysis and discussion that has been carried out, several conclusions can be drawn to answer the problem formulation that has been prepared, namely as follows: (1) Mobile games based on problem-based learning are effective in terms of learning motivation, learning interest and logical-mathematical thinking ability; (2) Mobile games based on conventional learning are effective in terms of learning motivation, learning interest and logical-mathematical thinking ability; (3) Mobile games based on problem-based learning are more effective than mobile game learning media based on conventional learning in terms of students' learning motivation, learning interest and logical-mathematical thinking ability.

Furthermore, this study has limitations that are expected to provide opportunities for other researchers conducting similar research to improve. The limitation is that it was limited to seventh-grade students at MTs Daarul 'Ulum 2 Sinar Melati and SMP Negeri 1 Minggir. Therefore, the results cannot be generalized more broadly. This provides an opportunity for other researchers to expand the study population.

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