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Synthesis of Research on Science Learning Management Affecting Problem Solving Skills: Meta-Analysis

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The rapidly changing world of the 21st century is complex and unpredictable. The researcher aimed to study the findings from a meta-analysis of 42 research studies related to the learning management of science that affects problem-solving skills during 2012–2022 from a database in Thailand called ThaiLIS. The findings revealed the variables that cause different mean effect sizes and the influence of research quality on the effect size. The instruments of this research were the research quality assessment form and the research characteristics assessment form. Statistics for data analysis were mean, standard deviation, one-way analysis of variance, and multiple regression analysis. The directional research hypothesis, multi-stage sampling, randomized control group post-test only design, PBL, and Weir's solution theory were discovered in the study to be the variables that caused the mean effect sizes to differ at the statistical significance level of .05. In addition, research quality had a positive influence on the effect size. The findings of this study will be useful to teachers who want to provide learning management of science that helps students develop problem-solving skills. This will develop skills more effective than traditional teaching.

Keywords: meta-analysis, research synthesis, problem-solving skills, science learning management, learning

INTRODUCTION

The rapidly changing world of the 21st century is complex and unpredictable. To develop and improve the potential of the people in the country in order to compete on an international level, the quality of education and learning management should be improved to meet international quality and standards in line with the world in the 21st century. Presently, learning management needs to be changed to give students 21st century skills, specifically problem-solving abilities. **(** National Education Plan 2017-2036, 2017**)**. Problem-solving skills are the ability to think, identify problems, and take

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action that requires a combination of knowledge and skills to result in appropriate problem-solving in each situation **(**The Institute for the Promotion of Teaching Science and Technology, 2018**)** . Therefore, problem-solving skills need to be cultivated, and instructional programs that develop problem-solving skills are designed appropriately for students at all levels in line with global changes, including the knowledge of science and technology that is growing rapidly **(**Ismet et al., 2020**)**.

Science and technology play an important role in today's and tomorrow's worlds because they are relevant to everyone's daily lives and careers. Science and technology also help humans develop ways of thinking, problem-solving skills, and scientific process skills, so learning science is an essential foundation that everyone must acquire in order to understand nature and technology **(**Ministry of Education, 2017**)**. However, research on the effects of science instruction on problem-solving skills is increasing, and the findings of the research are varied, making it difficult to draw conclusions. Therefore, research synthesis is an alternative method for summarizing findings from various studies. This provides useful and systematic knowledge for those who want to study the management of science learning that affects problem-solving skills.

Research synthesis is the process of acquiring knowledge through scientific methods by collecting research related to a problem for analysis by statistical methods or qualitative data analysis **(**Office of the Council of Education, 2009**)**. Analysis of research findings using statistical methods is known as meta-analysis. It is a type of quantitative research that involves studying the same research problem in multiple studies and using statistical analysis to reach a conclusion. The findings of the meta-analysis are measured in terms of effect size and the characteristics of the research. The analysis emphasizes the relationship between effect size and the characteristics of the research **(** Glass McGaw & Smith, 1981**)** . There have been many studies on meta-analysis. For example, Funa (2021) did a meta-analysis to analyze the effectiveness of problem-based learning on secondary student's achievement in different scientific disciplines. Ismaniati (2023) summarizes the overall effects of the flipped classroom model at Vocational High School in various majors with a meta-analysis approach.

For the previously mentioned reasons, The authors were interested in conducting a meta-analysis of research on science learning management affecting problem-solving skills using Cohen's effect size calculation by the G*Power program, which provides calculation formulas and other statistical calculations **(**Mayr et al.,2007**)**. The purposes of this study were as follows; 1) To study the characteristics of research on science learning management affecting problem-solving skills. 2**)** To analyze the differences in mean effect sizes classified by characteristics of research. 3) To study the influence of research quality on effect size. The results showed each variable that causes the average effect size to be different. Readers will know about learning management, problem-solving theories, and research methodologies that affect problem-solving skills. Furthermore, the research findings were used to benefit relevant parties in the development of problem-solving skills.

Literature Review

Science learning management

Science learning management is a method of learning management that includes a variety of methods for student-centered learning. It focuses on connecting scientific knowledge and processes to create new knowledge and skills through activities, working in groups, and using processes to find knowledge and solve problems. In addition, the essence of science has been defined as follows: biology, physical science, earth science, and technology (Ministry of Education, 2017) . According to learning theory, people learn when they are motivated and engaged in activities. As a result, teachers play an important role in assisting and encouraging students to participate in learning at every stage, leading to the creation of self-knowledge (Banilower et al., 2010).

Problem-solving skills

Problem-solving skills are the ability to recognize problems, look for and choose among different possible solutions, and make decisions so that all of the problems can be solved (Bariyyah, 2021). This skill is needed to bring together knowledge and skills to solve problems in the right way for each situation. In addition, problem-solving skills can show up as a problem-solving process where the instructors can come up with ways to teach by putting students in simulated situations or giving them information from real-life situations to practice solving problems (The Institute for the Promotion of Teaching Science and Technology, 2018).

Meta-analysis

Glass, McGaw, and Smith (1981) described meta-analysis as a sort of quantitative research that involves looking at the same research problem in several studies and drawing conclusions based on statistical analysis. These statistical analyses can be compared across various analysis results to see which aspects of analysis have the most educational potential. Meta-analysis can improve accuracy, answer questions that individual studies don't cover, and provide the opportunity to settle controversies arising from conflicting claims. Most meta-analysis methods are variations on a weighted average of the effect estimates from different studies, known as effect size (Higgins et al., 2019). Furthermore, meta-analysis investigates the relationship between research characteristics and effect size. The researcher looked at the documents and related research from Wiratchai and Wongwanich (1999) and categorized the characteristics of the research as follows: general information, research contents, research methodology, and research quality.

Effect size

Effect size is the main finding of a quantitative study; it is the difference between the average, or mean, outcomes in two different intervention groups. Effect size can refer to the raw difference between group means, or absolute effect size, as well as standardized measures of effect, which are calculated to transform the effect into an easily understood scale. In addition, calculated effect sizes can also be used to compare the

results of different studies quantitatively, so they are often used in meta-analyses (Sullivan and Feinn, 2012). In this study, the researcher used the G*Power program to calculate the effect size ,which led to Cohen's effect size (Mayr et al., 2007). Because the majority of the studies were experiments, the researchers used the G*Power program to calculate Cohen's effect size. The program has both direct and indirect formulas for figuring out the effect size from different types of experimental research, making effect sizes more accurate and reliable.

Research Conceptual Framework

The researcher looked at the documents and related research from Wiratchai and Wongwanich (1999) and categorized the characteristics of the research as follows: general information, research contents, research methods, and research quality. The researcher used the G*Power program to calculate the effect size, which led to Cohen's effect size (Mayr et al., 2007). Figure 1 shows characteristics of the research that affect the effect size.

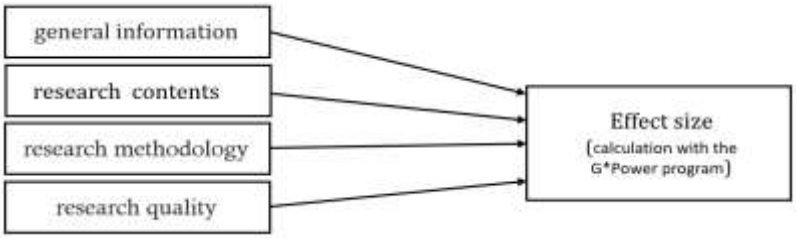

Figure 1
The characteristics of the research that affect the effect size from Wiratchai and Wongwanich (1999)

METHOD

The researcher proceeded with the following steps: First, search for research studied related to the learning management of science that affects problem-solving skills during 2012–2022 from ThaiLIS. Next, the researcher read the research to evaluate the quality of the research. After that, record research quality scores in the research quality assessment form. Next, the researcher selected research with an average quality score greater than 2.41 to read the research again to record the research characteristics in the research characteristics recording form. And finally, the researcher analyzed the data. Figure 2 shows the flow chart of the process for collecting data.

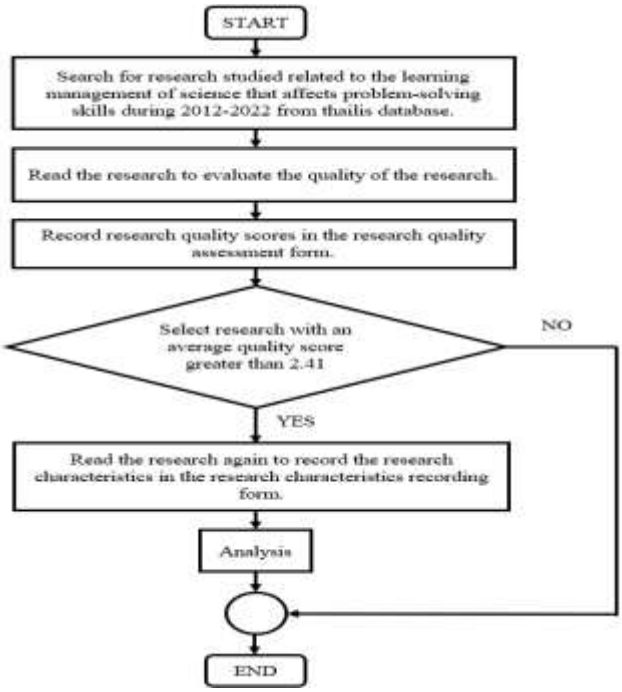

Figure 2
The flow chart shows the process for collecting data

Population and sample

The population is graduate research on learning management in science affects problem-solving skills that was published during 2012 - 2022 in ThaiLIS because ThaiLIS is a database that provides access to full-text electronic formats of dissertations, theses, journal articles, and rare books from university and institution libraries.

The sample group was research on learning management of science affecting problem-solving skills that was published between 2012 to 2022. They were derived from the purposive sampling that was selected according to the criteria set by the researcher.

Research selection criteria

1. Research on learning management in science affects problem-solving skills was conducted in Thailand from 2012 to 2022.
2. The research reported enough baseline statistics to be used to calculate the effect size.
3. The research quality was scored according to the criteria set by the researcher.

Research instrument

1. The research quality assessment form consisted of 24 items on a rating scale with 5 levels: low–high. The instrument had IOC value of 0.67–1 for all items after quality

inspection by experts, and the tools passed the inter rater reliability check with a correlation coefficient greater than 0.75.

2. The Research Characteristics Recording Form was a checklist form consisting of 4 sections as follows: general information, contents of the research information, research methodology information, and research quality. The tool had IOC value of 0.67–1 for all items after quality inspection by experts, and the tool was verified for internal consistency by all three recorders using Copper and Hedges' (1994) concordance interpretation criterion, which was evaluated as being 100% consistent, which was very good.

Data collection

The researcher collected data from October 2022 to November 2022 by searching for research published during the years 2012–2022 in the research database ThaiLIS.

Data analysis

The researcher analyzed the data as follows:
1. Basic statistics include percentage, frequency, mean, and standard deviation.
2. Cohen's (1988) effect size using the G*Power program.
3. Test the difference in the mean effect size using one-way ANOVA and multiple regression analysis.

FINDINGS

A total of 42 researches were synthesized in this study, and there were 68 effect sizes.

The results of the analysis of research characteristics on learning management in science affects problem-solving skills.

According to Table 1, Most of the published research was from 2018 to 2022 (15 books, 37.3%). The curriculum and teaching field of study published the most research (23 books 23.48%). Problem-based learning (PBL) was the most commonly used method in 23.5% of the studies and The sample used in the research was the most common random sample by cluster sampling (19 books, 45.3%). The experimental research design was the most one-group pretest-posttest design (31 books, 73.8%), and the most analytical t-test was used (28 books, 66.7%).

Table 1
The characteristics of research on the learning management in science affects problem-solving skills

Variable	Variable value	Frequency	%
Year of publication	2012 to 2014	14	33.3
	2015 to 2017	13	31.0
	2018 to 2022	15	35.7
	Total	42	100
Field of study	Curriculum and Teaching	23	54.8
	Research and Development for Education	3	7.1
	Science Education	11	26.2
	Computer education	2	4.8
	Educational Technology and Communication	3	7.1
	Total	42	100
Problem-solving Theory	mixed problem-solving theory	4	9.53
	Weir's Problem Solving Theory	25	59.52
	Torrance's future problem-solving theory	2	4.76
	SSPT's Problem Solving Theory	1	2.38
	Polya's Problem Solving Theory	1	2.38
	not specified	9	21.43
	Total	42	100
learning management of science (choose more than one item)	The 5Es of inquiry-based learning	11	16.2
	The 7Es of inquiry-based learning	7	10.3
	PBL (Problem-Solving Learning)	16	23.5
	PBL (Project-Based Learning)	3	4.4
	STEM	8	11.8
	Integrated Learning Management	7	10.3
	Online lesson	3	4.4
	future problem-solving	2	2.9
	Metacognitive strategy	2	2.9
	The Four Noble Truths teaching method	2	2.9
	Science Technology and Society approach	3	4.4
	Etc.	4	6.0
	Total	68	100
Types of probability sampling	Simple random sampling	16	38.1
	Cluster sampling	19	45.3
	Multi-stage sampling	3	7.1
	not specified	4	9.5
	Total	42	100
Types of experimental research designs	A one-group pretest–posttest design	31	73.8
	nonrandomized posttest only control group design	1	2.4
	nonrandomized pretest-posttest control group design	4	9.6
	Randomized Posttest-Only Control Group Design	2	4.8
	Randomized pretest -posttest control group design	3	7.1
	Control group time series design	1	2.4
	Total	42	100
Statistical analysis	t-test dependent	28	66.7
	t-test independent	1	2.4
	One – Way ANCOVA	2	4.8
	MANCOVA	1	2.4
	Repeated Measure ANOVA	1	2.4
	ANCOVA	1	2.4

Variable	Variable value	Frequency	%
	Hotelling T^2	4	9.6
	MANOVA	3	7.2
	wilcoxon signed rank	1	2.4
	not specified	1	2.4
	Total	42	100

According to Table 2, the average research sample size was 42 people (max = 88, min = 10), and it took an average of 17.26 hours to complete the experiment. The average reliability of research tools was 0.84 (max = 0.98, min = 0.68). The average effect size of the study was 2.64 (max = 7.57, min = 0.26).

Table 2
The continuous variables in research

Variable	Amount	Mean	S.D.	Minimum	Maximum
Sample size	42	45	19.48	17	88
Time (hours)	40	17.26	6.50	9.00	39.00
instrument Reliability	60	0.84	0.08	0.68	0.98
Effect size	68	2.64	1.44	0.26	7.57

The researcher defined the criteria for interpreting the Office of the Education Council's (2009) research quality assessment average score as follows: very high quality (3.21-4.00), high quality (2.41-3.20), moderate quality (1.61-2.40), quite low quality (0.81-1.60), and low quality (0.80).

According to Table 3, the research had an average quality score of 3.06, which is divided into 4 parts as follows: Research methodology and data analysis had the highest average quality score of 3.29 (very high quality); concluding, discussion, and suggestion had the average quality score of 3.14 (high quality); the literature review had the average quality score of 2.89 (high quality); and the introduction had the average quality score of 2.85 (high quality).

Table 3
The characteristics of research in terms of research quality

Part	Research quality	Assessment results		
		Mean	S.D.	Quality
1	Introduction	2.85	1.16	High
2	literature review	2.89	0.84	High
3	Research methodology and data analysis	3.29	0.77	Very high
4	Concluding, discussion, and suggestion	3.14	0.84	High
	Total	3.06	0.96	High

The results of the mean effect size difference analysis are classified according to the characteristics of the research

As shown by Table 4, there were nine variables with different mean effect sizes at the 0.05 significant level. The publication year variable found that 2015-2017 (Mean = 3.27, S.D. = 1.66) had a higher average effect size than 2012–2014 (Mean = 2.22, S.D. = 1.38) and physical science (Mean = 3.45,

S.D. = 1.82) had a higher average effect size than technology (Mean = 1.53, S.D. = 0.55).

The problem-solving theory variable found that Weir's problem-solving (Mean = 3.07, S.D. = 1.54) had a higher mean effect size than the research that did not identify the problem-solving theory (Mean = 1.77, S.D. = 1.08); problem-based learning (Mean = 3.63, S.D. = 1.85) had a higher mean effect size than integrated learning (Mean = 1.70, S.D. = 0.69); and the directional hypothesis (Mean = 2.85, S.D. = 1.52) had a higher mean effect size than the non-directional hypothesis (Mean = 1.89, S.D. = 0.78). Furthermore, multi-step sampling, cluster sampling, and simple random sampling were found to have a higher mean effect size than research that did not specify random sampling. The randomized posttest-only control group design (Mean = 3.81, S.D. = 1.78) had a higher mean effect size than the experimental research design that used a nonrandomized pretest-posttest control group design (Mean = 1.62, S.D. = 1.09) and the Hotelling T^2 statistics and reliability Lovett had the highest average effect size.

Table 4
The mean effect size difference analysis of the research is classified by the characteristics of the research

Variable	Variable Value	Effect size			Test of homogeneity of Var.		ANOVA	
		n	$\bar{d}$	S.D.	F	P	F	P
Year of publication (general information)	2012 to 2014	26	2.22	1.38	1.28	0.28	3.22	0.046*
	2015 to 2017	20	3.27	1.66	The analytical results were significantly different at 0.05. 2015 to 2017 > 2012 to 2014			
	2018 to 2022	22	2.56	1.12				
Subject (research contents)	Physical science (Physic and Chemistry)	36	2.79	1.45	2.00	0.12	2.87	0.044*
	Biology	13	2.28	1.22	The analytical results were significantly different at 0.05. Earth science, Physical science > Technology			
	Earth science	6	3.45	1.82				
	Technology	8	1.53	0.55				
Problem-solving Theory (research contents)	mixed problem-solving theory	5	2.23	0.90	1.84	0.12	2.41	0.046*
	Weir's Problem Solving Theory	42	3.07	1.54	The analytical results were significantly different at 0.05. Weir's Problem Solving Theory > not specified			
	Torrance's future problem-solving theory	2	1.41	0.42				
	SSPT's Problem Solving Theory	3	2.33	0.76				
	Polya's Problem Solving Theory	2	2.40	0.14				
	not specified	14	1.77	1.08				
Learning management in science (research contents)	inquiry-based learning (5E, 7E)	18	3.09	1.38	4.07	0.01		
	PBL (Problem-Based Learning)	16	3.63	1.85	Welch, F=6.11 ,Sig = 0.002** The analytical results were significantly different at 0.05. PBL > Integrated Learning Management, Etc.			
	STEM	8	2.43	0.81				
	Integrated Learning Management	7	1.70	0.69				
	Etc.	19	1.82	0.72				
Types of research hypotheses (research methodology)	Directional research hypothesis	53	2.85	1.52	t-test independent The analytical results were significantly different at 0.05. t = 3.33 , Sig = 0.002*			
	Nondirectional research hypothesis	15	1.89	0.78				
Types of probability	Multi-stage sampling	4	3.64	2.69	4.697	0.01		
	Cluster sampling	34	2.73	1.35	Welch, F=4.962 ,Sig =0.018*			

Variable	Variable Value	Effect size			Test of homogeneity of Var.		ANOVA	
		n	$\bar{d}$	S.D.	F	P	F	P
sampling (research methodology)	Simple random sampling	17	2.90	1.51	The analytical results were significantly different at 0.05. Multi-stage sampling, Cluster sampling, Simple random sampling > not specified			
	not specified	13	1.76	0.63				
Types of experimental research designs (research methodology)	one-group pretest–posttest design	45	2.68	1.27	1.479	0.22	2.99	0.025*
	nonrandomized posttest only control group design	2	1.79	0.46	The analytical results were significantly different at 0.05. randomized posttest - only control group design > nonrandomized pretest-posttest control group design			
	nonrandomized pretest-posttest control group design	10	1.62	1.09				
	Randomized posttest-only control group Design	5	3.81	1.78				
	Randomized pretest-posttest control group design	5	2.48	0.63				
Statistical analysis (research methodology)	t-test dependent	43	2.65	1.31	2.217	.08	2.69	0.039*
	t-test independent	4	1.37	0.92	The analytical results were significantly different at 0.05. Hotelling T^2 > t-test dependent > t-test independent , Etc.			
	One-way ANOVA	3	2.70	1.06				
	Hotelling T^2	10	3.64	2.07				
	Etc.	8	1.95	0.65				

The results of the research quality analysis on the effect size

As shown by Table 5, The results of the multiple regression analysis revealed that quality in all four aspects had a positive influence on the effect size at the statistically significant 0.05 level. The quality of the conclusion, discussion, and suggestion had the most positive influence (β = 0.364), followed by the literature review (β = 0.360) and research methodology and data analysis had the least positive influence (β = 0.213). The research quality in all four aspects explained 58.4% of the variance in effect size.

Table 5
Influence of research quality to effect size

Variable	b	SE	β	t	Sig
Introduction	1.131	0.540	0.235	2.096	0.043*
literature review	1.951	0.578	0.360	3.376	0.004*
Research methodology and data analysis	1.341	0.658	0.213	2.037	0.049*
Conclusion, discussion, and suggestion	1.522	0.502	0.364	3.035	0.002*

DISCUSSION

Discussion of the analysis of research characteristics on science learning management affecting problem-solving skills

Characteristics of research in general information: the most research was published during 2018-2022, followed by 2012-2014, because of the increased awareness of teaching and learning science that develops 21st century skills that are essential for students to be able to creatively apply to real-life problems (Ministry of Education Thailand, 2017). Curriculum and teaching were the most researched fields because they paid attention to how curriculum, content, techniques, and methods of teaching can be

used to organize teaching and learning to help students develop skills that they can use in everyday life.

Characteristics of research in research contents: the study found that most of the research used Weir's problem-solving theory because it is a clear and systematic problem-solving process. The learning management method in science that was found most frequently in the research was problem-based learning (PBL), followed by inquiry-based learning (5E). Both types of teaching and learning are student-centered and involve a process of searching, exploring, finding answers, researching in various ways, and also practicing solving problems through a systematic thinking and practice process that leads to the development of essential skills for 21st century learners (Office of the Basic Education Commission, 2019).

Characteristics of research in methodology: cluster sampling was most commonly used to conduct research because the samples were arranged in classrooms. Therefore, it is suitable for group randomization, and the sample group has an average of 45 people. The one-group pretest-posttest is the most common way to do experimental research, so the dependent t-test is the most common way to look at data.

Discussion the results of the mean effect size difference analysis, which are classified according to the characteristics of research

The following variables had significantly different mean effect sizes: The research published during 2015-2017 had a higher mean effect size than the research published during 2012-2014 because it is the result of being alert to teaching and learning to aim to develop students according to the basic education core curriculum since 2008. In the past, educators studied, researched, improved, and created new ways to teach and learn so that they could be more effective and help students develop their skills to the fullest. In terms of subject variables, it is found that the average effect sizes of earth science and physical science subjects are higher than those of technology subjects because this study's sample group consisted of students enrolled in the science and mathematics study plan. Most students will have an interest in and basic knowledge of science because they study science subjects in lower secondary school, which is a required education for all students and corresponds to the Basic Education Core Curriculum 2008 (Ministry of Education Thailand, 2008).

Weir's problem-solving theory in research has a higher mean effect size than research conducted without using the theory because Weir's theory provides systematic, structured, and procedural learning in solving problems that is more appropriate and clear than research that does not specify theories or concepts to solve problems (Weir, 1974).

The management of instruction and learning revealed that problem-based learning has a higher mean effect size than integrated learning management because problem-based learning is a learning management model that allows learners to create new knowledge by using real-world problems as a learning context for students to develop problem-solving skills. Problem solving is the result of a work process that relies on understanding and solving problems. It gets students to take action and deal with

problems on their own, giving them a chance to practice how to solve problems. The problem-solving skills of students learned using problem-based learning are better than conventional learning, which consists of lectures and discussions. (Sari et al., 2021). Activities of problem-based learning create an opportunity for modeling and eliciting feedback, a skill that should be developed among students to support problem-solving skills (Magaji, 2021).

In the past, there have been studies on problem-based learning such as those by Phumeechanya and Wannapiroon (2013) that develop ubiquitous teaching using the PBL model, which can improve students' problem-solving skills. Shin and Kim (2013) conduct a synthesis of research on PBL that affects nurses. The research results found that PBL has a positive effect on the satisfaction and problem-solving skills of nurses.

In terms of hypothetical variables, it was found that the research with a directional hypothesis had a higher mean effect size than the research with an undirected hypothesis because directional assumptions would help with planning research and understanding the study variables. In addition, directional hypotheses can help guide the data collection, analysis, and conclusions. The interpretation of research results is based on assumptions, which makes interpretation and drawing conclusions easier (Ghauri and Gronhaug, 2002).

From the randomization study, it was found that the research using cluster sampling, multistage sampling, or simple random sampling had higher mean effect sizes than unspecified studies because the identification of clear randomization demonstrates that the researcher has a good understanding of the population and sample. Furthermore, random sampling methods enable a sample to be well representative of the population in order to draw conclusions that have both internal and external validity (Bhardwaj, 2019).

Randomized posttest only control group design with a mean effect size higher than a nonrandomized pretest-posttest control group design. Randomized posttest only control group design can be randomized to make the two sample groups statistically comparable. This design doesn't have a pre-test to control outside factors that affect internal validity, so there aren't any external problems caused by the pre-test and the experiment (Kevin et al., 2018).

Finally, Hotelling's T^2 statistic had a higher mean effect size than the t-test statistic because it has high testing power, and the error from the data analysis is small (Randall, 2015) . Therefore, the research using Hotelling's T^2 statistics has a high mean effect size.

Discussion the results of the research quality analysis on the effect size

The total quality of the research was 3.06, which was a high level. From the results of the multiple regression analysis, it was found that research quality has an influence on the mean effect size. It shows that if the research quality is high, the effect size will increase. The quality of research in the aspects of conclusion, discussion, and suggestion had the most positive influence on the effect size ($\beta = 0.364$) because this aspect has important steps. The effect size will increase if the research can complete the

aforementioned steps with quality. The literature review has a positive influence on the effect size (β =0.360) because this aspect is related to the literature review, which includes variable studies. As a result, a researcher has knowledge and a deep understanding, obtains guidelines for research design, and makes known the problems, obstacles, and limitations of the research. For the reasons mentioned previously, it is possible to obtain research with a large effect size. However, the researcher found that the average quality of the introduction was still the lowest. Most research papers also need to improve on their preliminary agreements, because these are the sections that help readers and researchers understand each other's research problems and concerns about the findings. In addition, research conceptual frameworks need to be improved and developed because the research conceptual framework is an important part that helps make all stages of research clear and reliable (National Center for the Dissemination of Disability Research, 2005).

CONCLUSION

The research results are divided into three parts. In the first part, regarding the research characteristics, it is found that the learning management method in science that is found in most research is problem-based learning, which is based on Weir's problem-solving theory. The one-group pretest-posttest design is the most common way to do experimental research. Therefore, the most commonly used statistic for data analysis is the dependent t-test. In the next part, the following variables have significantly different mean effect sizes: multi-stage sampling, randomized control group post-test only design, problem-based learning, Weir's solution theory, randomized posttest only control group design, and Hotelling's T^2 statistic, which were discovered in the study to be the variables that caused the mean effect sizes to be significantly different at 0.05. And in the last part, The research quality has a positive influence on the mean effect size, and the quality of the research in the aspects of conclusion, discussion, and suggestion had the most positive influence on the effect size ($\boldsymbol{\beta}$ = 0.364).

SUGGESTION

Suggestions for applying the research results

Problem-based learning (PBL) should be promoted along with Weir's problem-solving theory because it will give students a clear and systematic way to solve problems that will help them get better at solving problems.

In research, a true experiment design (randomized posttest-only control group design or randomized pretest-posttest control group design) is essential because it enables the effective control of extraneous variables. Furthermore, it is a more effective research model for developing learners' problem-solving skills than the one-group pretest-posttest design.

Randomization should be used in research to control the extraneous variable so that it has the least effect on the problem-solving skills. In addition, research with at least two dependent variables should be encouraged because high-powered statistics are needed to analyze the data, which makes the results of data analysis less wrong.

The research quality of the introduction was discovered to be of the lowest average quality because most studies did not indicate preliminary agreement. Furthermore, most research conceptual frameworks are also not complete, so research should be developed in terms of preconditions and research conceptual frameworks to promote higher research quality.

Suggestions for further research

The problem-based learning (PBL) method and Weir's theory about how to solve problems should be combined and developed into a new teaching model that will help students learn how to solve difficult and complex problems well.

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