Vol 10(1) (2021): 40-47
DOI: http://dx.doi.org/10.24235/sc.educatia.v10i1.8486

SCIENTIAE EDUCATIA: JURNAL PENDIDIKAN SAINS

http://www.syekhnurjati.ac.id/jurnal/index.php/sceducatia

The Effectiveness of Science Learning Research Skills: A Meta-Analysis Study

Ipin Aripin [a,b*], Topik Hidayat[c], Nuryani Rustaman[c,d], Riandi[c,d]

[a] Science Education, Graduate School, Universitas Pendidikan Indonesia, Indonesia
[b] Department of Biology Education, Faculty of Teacher Training and Education, Universitas Majalengka, Indonesia
[c] Department of Biology Education, Faculty of Mathematics and Natural Science Education, Universitas Pendidikan Indonesia, Indonesia
[d] Graduate School, Universitas Pendidikan Indonesia, Indonesia

[*]Corresponding author: Dusun Kaler RT 16/05 Desa Sindanghaji, Kecamatan Palasah, Kabupaten Majalengka, Jawa Barat 45475, Indonesia. E-mail addresses: ipin_aripin@upi.edu

article info

Article history:
Received: 01 April 2021
Received in revised form: 20 May 2021
Accepted: 20 June 2021
Available online: 30 June 2021

Keywords:
Science learning
Research skills
Inquiry

abstract

Research skills are our ability to find and answer a question or solve a problem. This study aimed to identify methods in the science learning of research skills. Meta-analysis study used PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) method. The stages of the research method include: determining criteria and literature search techniques, conducting literature analysis, coding, and data analysis. Jeffreys's Amazing Statistics Program (JASP) version 0.14.1 was used as a data analysis tool. A total of (n=16) articles were taken from Indonesia and overseas being analyzed. Research findings showed that learning through research skills gave effect around 0.63 (medium). The Inquiry method was the most effective and used in learning through research skills. Based on the research findings above, it can be concluded that there were ten effective methods in learning through research skills. The inquiry method could be recommended in the learning through research skills in the schools and college level.

1. Introduction

21st-century science education aims to empower students to acquire scientific knowledge in any discipline and solve the problem through scientific methods known as research skills (Fischer et al., 2014; Maddens et al., 2020). Research skills are needed to face competition in the 21st century (Roito et al., 2019). According to the National Research Council (2010), research skills build scientific skills and develop other skills such as problem-solving and communication skills, so building research competencies is an essential agenda in 21st-century education (Fischer et al., 2014; Maddens et al., 2020).

Research competencies refer to someone's skills in implementing scientific methods like identifying, constructing a hypothesis, selecting variables, experimenting, and interpreting the data (Yalcin, 2015). According to Meerah & Arsad (2010), research skills are the ability to conduct research using tools, strategy, problem-solving skills, critical thinking, and explaining the research findings. The Research Competencies Framework (RCF) is divided into research competence groups such as practical skills, dissemination, problem-solving skills, thinking and

communication, attitudes, professional ethics, dissemination, knowing the role and aim of the research (FGDP, 2007).

Fischer et al. (2014) and Opitz et al. (2017) conceptualize indicators of research skills, namely identifying problems, formulating research questions, determining hypotheses, designing research, collecting data, evaluating data, drawing conclusions, and communicating research results. (Davidson & Palermo, 2015) stated other indicators of research skills: designing research, determining samples, selecting respondents, collecting data, statistical testing, reporting, and presentations.

Biology research skills have essential requirements to give experience to students (Maknun et al., 2020). Research skills are essential in the working environment because the company can continue doing research and business development (Bandaranaike, 2018). Research skills frameworks and working ability are related to each other. This skill is the basic to develop working ability (Bandaranaike, 2018).

Mastering research skills should be the primary competence for science teachers in Indonesia because developing research skills is the primary purpose in science education (Anggraeni et al., 2017). According to Maknun et al. (2020), the pre-service teacher has to improve the research skill; however, the teacher has not explained to the students about research skills.

The achievement of research skill competencies in Indonesia at the secondary and higher education levels is still relatively low, which is confirmed by research conducted by Sari et al. (2019); Roito et al. (2019); and Nurlaelah et al. (2020) with the conclusion that students still lack mastery of research procedures, implementation, and reporting. At the university level, the mastery of research skills is low, especially in the aspect of intellectual ability (Aripin et al., 2021), the implementation stage of research (Solihat, 2015; Maknun et al., 2020), and research data analysis (Subekti et al., 2018). Willison (2018) developed a Research skill development (RSD) framework integrated into the learning curriculum to evaluate and classify students' research skills based on autotomy level.

Based on the explanation above, the researcher is interested in analyzing various research methods to provide students with research skills. The results of this study can be helpful to recommendations for teachers in delivering practical research skills through appropriate learning methods.

2. Method

Meta-analysis study was a statistical technique to combine similar research in integrating the data findings. The study used the Prisma method (Haidich, 2010; Ogurlu, 2020). This study uses the PRISMA method (Moher et al., 2009).

This research data was eligible in some criteria: the research conducted in primary, secondary, and higher education. The object of the research was a science course. The subject of the research was students, teachers, and lecturers. The references are taken from journal, national, and international proceedings publications that have been published. The researcher tried to find similar literature through www.sciencedirect.com, https://www.tandfonline.com/, https://eric.ed.gov/, and https://onlinelibrary.wiley.com/. Google Scholar was not used as a reference in this study with the consideration that the data generated was not specific to the search target (Peter et al., 2019).

Finding the data used keywords "*keterampilan riset*," "*keterampilan meneliti*," "research skills," and "research ability." The researcher found 22902 documents. After the author had checked the journal, there was much duplication, so the researcher decided to decrease the keywords "*keterampilan riset*," "*keterampilan meneliti*," and "research skills," getting 1002 data. After

verification based on the criteria, there were 52 criteria closer to the criteria and pursed into 31 because some researchers were not in a science topic. The researcher did not find any detailed research findings in literature studies. The research findings obtained 16 research data that are relevant to the analysis. Data collection follows the following PRISMA procedure.

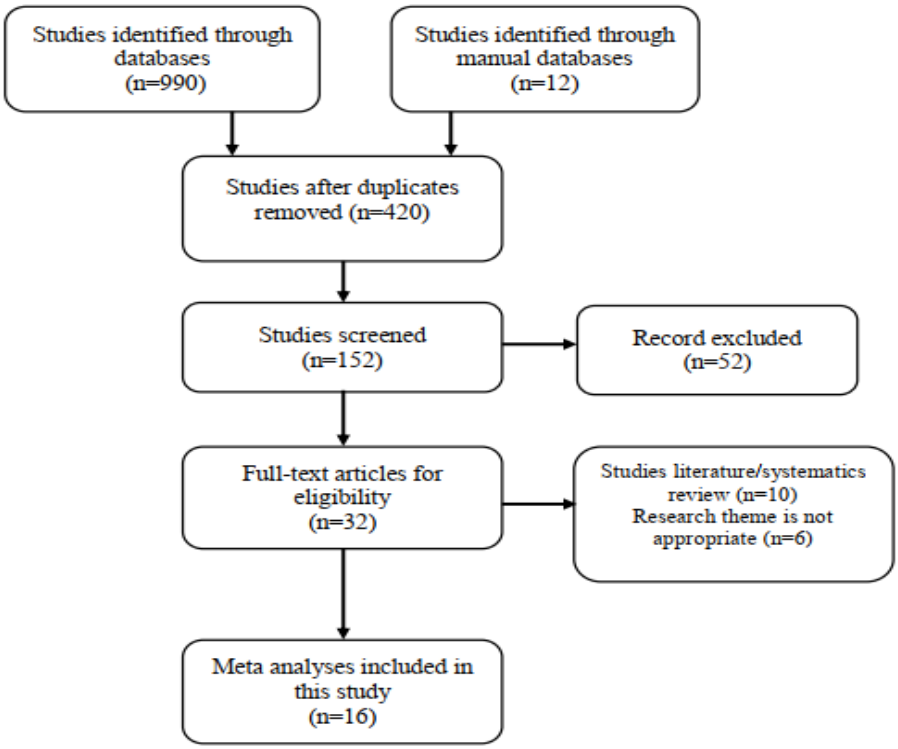

Figure 1. PRISMA Flowchart

The researcher did coding by reading the abstract and identifying conclusion. The researcher identified the author, research objective, actions, research methodology, sample, research object, and research findings (effect size). The data was analyzed through the meta-analysis technique. Jeffreys's Amazing Statistics Program (JASP) version 0.14.1 was used as data analysis in mapping effect size and forest plot. The criteria in selecting effect size based on Cohen criteria (1992) in range 0.20-0.50 "Low", 0.50-0.80 "medium" and > 0.80 "high". The homogeneity test in effect size used 12 parameters if it closed to 100%. It showed that the effect size was getting homogenous (Retnawati et al., 2018). The bias publication was analyzed through funnel plot if the points distribution did not cover and it was blank points form without a black mark to indicate that the data had biased publication (Retnawati et al., 2018).

3. Result and Discussion

The PRISMA method results were 16 relevant results to be analyzed, (n=6) from Indonesia (n=8) from international research. The total distribution is presented in Table 1.

Table 1. Distribution of research data

No.	Authors	Methods	Year	Level*	Sample
1.	Azizah, A & Parmin, 2012	Guided inquiry	2012	Bch	42
2.	Roito, E. et al., 2019	Step-by-step-model	2019	SHC	32
3.	Maknun, D., 2019	Project-based	2019	Bch	91
4.	Gyuris, E., 2018	Research skill training	2018	Bch	61
5.	Prahmana, R. C. I., 2015	Project-based	2015	Bch	20

No.	Authors	Methods	Year	Level*	Sample
6.	Solihat, R. et al., 2015	Personal reflection	2015	Bch	85
7.	Nurlaelah, I. et al., 2020	Practice	2020	JHC	68
8.	Suatma et al., 2012	Research teaching materials	2012	Bch	68
9.	Sabirova, E. G., & Zakirova, V., 2014	Experiment	2014	ES	270
10.	Craig, R. & Bielenberg, B., 2015	Inquiry	2015	Bch	252
11.	Chu, 2008	Inquiry-based learning	2008	ES	141
12.	Rodríguez, G., et al., 2019	Inquiry based learning	2019	Bch	529
13.	Bortnik, B. et al., 2017	Virtual analytical chemistry laboratory	2017	Bch	50
14.	Maskall, J. & Cotterell, S., 2011	Project-based	2015	Bch	84
15.	Abbott, D., 2019	Game-based learning	2019	Bch	127
16.	Subekti, H., et al., 2018	Experience study	2018	Bch	302

*(Bch= bachelor; SHC= senior high school; JHC= junior high school; ES= elementary school)

The data distribution showed in table 1. The research skill method mainly was used the inquiry method (Azizah & dan Parmin, 2012); (Craig & Bielenberg, 2015); (Chu, 2008); (Rodríguez et al., 2019); project-based learning (Maknun et al., 2019); (Maskall & Cotterell, 2011), (Prahmana, 2015), Step-by-Step-model (Roito et al., 2019); Research skills training (Gyuris, 2018); personal reflection (Solihat, 2015); practicum (Nurlaelah et al., 2020); experiments (Sabirova & Zakirova, 2015); virtual laboratory (Bortnik et al., 2017); game-based learning (Abbott, 2019); experience study (Subekti et al., 2018). A total of two studies were carried out at the elementary school level (Sabirova & Zakirova, 2015); (Chu, 2008); one research at the junior high school level (Nurlaelah et al., 2020) and one research at the high school level (Roito et al., 2019), the rest were carried out in universities.

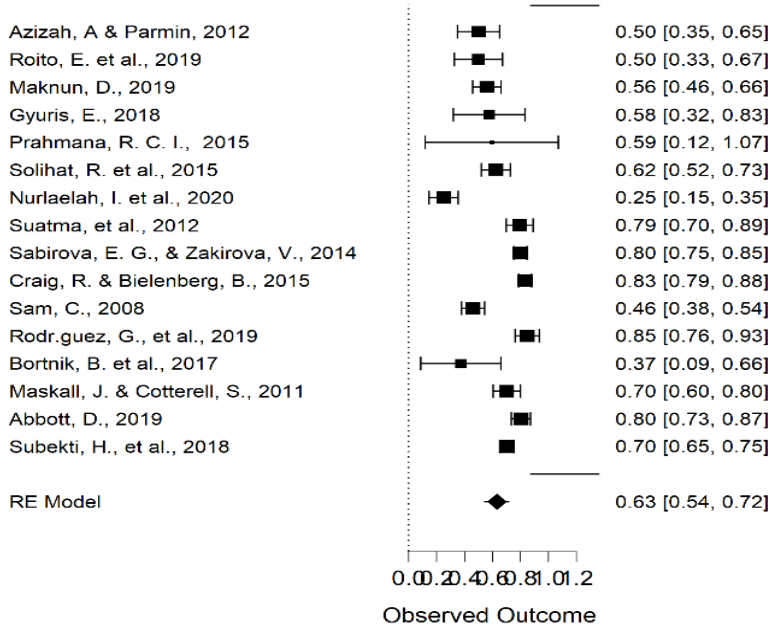

Figure 2. Distribution of effect size data on research results

The distribution of the effect of the methods used in this research is shown in table 1 with low impact (Nurlaelah et al., 2020). The highest effect in this reseacrh (Rodríguez et al., 2019). The whole research data plots were in the proper dividing line, indicating that all the research positively impacted the research skills. The method had used in this research enhanced the research skills in 0.63 or the medium category.

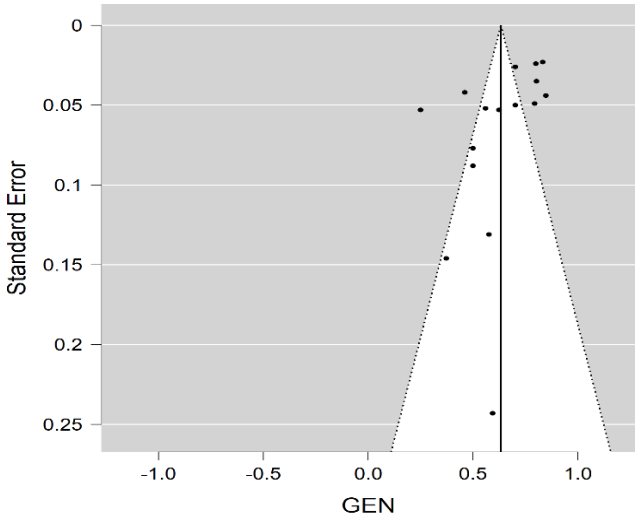

Figure 3. Funnel Plot Research Skills Learning Method

The research distribution is distributed and homogenous, shown in figure 3. There were no blank points distribution data; it can be explained that there was no bias publication. In table 2 shows the homogeneity test.

Table 2. Homogeneity of research data

Residual Heterogeneity Estimates			
		95% Confidence Interval	
	Estimate	Lower	Upper
τ^2	0.028	0.013	0.064
τ	0.166	0.113	0.253
I^2 (%)	93.458	86.916	97.083
H^2	15.285	7.643	34.277

In table 2 shows the homogeneity test parameters I^2 93,458 or 93.5%, close to 100%, and τ^2 0.05. Based on the data above, it can be explained that all the data can not be replaced or dropped.

The meta-analysis findings showed that the contribution of research skills could make a positive contribution to enhancing research skills. The inquiry method can be chosen as an alternative learning research skill. The inquiry method was used by Azizah & dan Parmin (2012), Craig & Bielenberg (2015), Chu (2008), and Rodríguez et al. (2019) explained a hugely positive effect and reasonable contribution to the research skills learning.

Rangkuti (2016) explained that inquiry was a recommended method in teaching research skills at the university level. The inquiry was the way for scientists to develop new knowledge and understand scientific obtain knowledge (Lederman et al., 2013; Smith et al., 2020). Based on the explanation above, it can be concluded that scientists used inquiry to conduct research and develop knowledge. Lederman et al. (2013) explained that inquiry was one way to understand science and solve daily life problems. The inquiry was a basis for developing science and scientific literacy (Smith et al., 2020).

Project-based learning methods (Maknun, et al., 2019); (Maskall & Cotterell, 2011), research-based learning (Prahmana, 2015), Step-by-Step-model (Roito et al., 2019); Research skills training (Gyuris, 2018); personal reflection (Solihat, 2015); practicum (Nurlaelah et al., 2020); experiments (Sabirova & Zakirova, 2015); virtual laboratory (Bortnik et al., 2017); game-based learning (Abbott, 2019); experience study (Subekti et al., 2018) explained that this method gave the influence to research skills. All method analysis had a positive effect on improving research

skills with various effects. Inquiry and project-based learning were often used to develop research skills at the university level. According to Rangkuti (2016), inquiry and project-based learning were suitable to enhance research skills in the university. Project-based learning allowed the students to learn through investigation, collaborative research, and creating projects that represent their knowledge (Bell, 2010).

The development of research skills can be done with an integrated curriculum that is able to facilitate students to develop thinking skills and research processes (Willison & O'Regan, 2007; Willison, 2012; Torres, 2018). In the selection, an appropriate had shown from meta-analysis result, and it can be an option for teachers to develop student's research skills.

4. Conclusion

The meta-analysis result found that the average of the research skills method was 0.63 (medium). This research found ten methods that give a positive effect to enhance research skills. The inquiry was one strategy that provides significance in practice and develops research skills. Research methods like problem-based learning, cooperative learning, mini-research, and citizen science were not conducted so that they can be continued for the following research.

References

Abbott, D. (2019). Game-based learning for postgraduates: An empirical study of an educational game to teach research skills. *Higher Education Pedagogies*, *4*(1), 80–104. https://doi.org/10.1080/23752696.2019.1629825

Anggraeni, N., Adisendjaja, Y. H., & Amprasto, A. (2017). Profile of High School Students' Understanding of Scientific Inquiry. *Journal of Physics: Conference Series*, *895*(1). https://doi.org/10.1088/1742-6596/895/1/012138

Aripin, I., Hidayat, T., Rustaman, N., & Riandi, R. (2021). Prospective biology teachers' research skills. *Journal of Physics: Conference Series*, *1806*(1). https://doi.org/10.1088/1742-6596/1806/1/012170

Azizah, A., & dan Parmin. (2012). Inquiry Training Untuk Mengembangkan Keterampilan Meneliti Mahasiswa. *USEJ - Unnes Science Education Journal*, *1*(1). https://doi.org/10.15294/usej.v1i1.848

Bandaranaike, S. (2018). Research Skill Development to Work Skill Development. *Journal of University Teaching & Learning Practice*, *15*(4). https://ro.uow.edu.au/jutlpAvailableat:https://ro.uow.edu.au/jutlp/vol15/iss4/7:https://ro.uow.edu.au/jutlp/vol15/iss4/7

Bell, S. (2010). Project-Based Learning for the 21st Century: Skills for the Future. *The Clearing House: A Journal of Educational Strategies, Issues, and Ideas*, *83*(2), 39–43. https://doi.org/10.1080/00098650903505415

Bortnik, B., Stozhko, N., Pervukhina, I., Tchernysheva, A., & Belysheva, G. (2017). Effect of virtual analytical chemistry laboratory on enhancing student research skills and practices. *Research in Learning Technology*, *25*(1063519), 1–20. https://doi.org/10.25304/rlt.v25.1968

Chu, S. (2008). Grade 4 Students' Development of Research Skills through Inquiry-Based Learning Projects. *School Libraries Worldwide*, *14*(1), 10.

Cohen, J. (1992). Statistical Power Analysis. *Current Directions in Psychological Science*, *1*(3), 98–101. https://doi.org/10.1111/1467-8721.ep10768783

Craig, R., & Bielenberg, B. (2015). Promoting a culture of inquiry: Foregrounding research skills in first and second-year engineering students. *QScience Proceedings*, *2015*(4), 14. https://doi.org/10.5339/qproc.2015.wcee2014.14

Davidson, Z. E., & Palermo, C. (2015). Developing Research Competence in Undergraduate Students through Hands-on Learning. *Journal of Biomedical Education*, *2015*, 1–9. https://doi.org/10.1155/2015/306380

FGDP. (2007). *Research Competencies Framework*. The Royal College of Sugeons of England.
Fischer, F., Kollar, I., Ufer, S., Sodian, B., Hussmann, H., Pekrun, R., Neuhaus, B., Dorner, B., Pankofer, S., Fischer, M., Strijbos, J. W., Heene, M., & Eberle, J. (2014). Scientific reasoning and argumentation: Advancing an interdisciplinary research agenda in education. *Frontline Learning Research*, *2*(3), 28–45. https://doi.org/10.14786/flr.v2i3.96
Gyuris, E. (2018). Evaluating the effectiveness of postgraduate research skills training and its alignment with the research skill development framework. *Journal of University Teaching and Learning Practice*, *15*(4).
Haidich, A.-B. (2010). Meta-analysis in medical research. *Hippokratia*, *14*(1), 29–37. https://doi.org/10.1136/bmj.1.4346.572-a
Lederman, N. G., Lederman, J. S., Nature, A., Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of Science and Scientific Inquiry as Contexts for the Learning of Science and Achievement of Scientific Literacy. *International Journal of Education in Mathematics, Science and Technology*, *1*(3), 138–147. https://doi.org/10.18404/ijemst.19784
Maddens, L., Depaepe, F., Janssen, R., Raes, A., & Elen, J. (2020). Research skills in upper secondary education and first year of university. *Educational Studies*, *47*(4), 491–507. https://doi.org/10.1080/03055698.2020.1715204
Maknun, D., Gloria, R. Y., & Muzakki, J. A. (2019). *Model Kerja Lab Berbasis Proyek Untuk Meningkatkan Keterampilan Meneliti Dan Kesadaran Eko-Spiritual Mahasiswa S1 Program …. 65*. http://repository.syekhnurjati.ac.id/3197/
Maknun, D., Gloria, R. Y., & Muzakki, J. A. (2020). Keterampilan meneliti yang dimiliki mahasiswa prodi pendidikan biologi se-wilayah III Cirebon. *Jurnal Inovasi Pendidikan IPA*, *6*(1), 39–47. https://doi.org/10.21831/jipi.v6i1.28251
Maskall, J., & Cotterell, S. (2011). A project-based approach to research skills development in first year undergraduates. *Planet*, *24*(1), 22–29. https://doi.org/10.11120/plan.2011.00240022
Meerah, T. S. M., & Arsad, N. M. (2010). Developing research skills at secondary school. *Procedia - Social and Behavioral Sciences*, *9*, 512–516. https://doi.org/10.1016/j.sbspro.2010.12.189
Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, *6*(7). https://doi.org/10.1371/journal.pmed.1000097
National Research Council. (2010). *"Exploring the Intersection of Science Education and 21st Century Skills: A Workshop Summary." In Margaret Hilton, Rapporteur, Board on Science Education, Center for Education, Division of Behavioral and Social Sciences and Education*.
Nurlaelah, I., Widodo, A., Redjeki, S., & Rahman, T. (2020). Student's research skills in middle school of Kuningan district. *Journal of Physics: Conference Series*, *1521*(4). https://doi.org/10.1088/1742-6596/1521/4/042105
Ogurlu, U. (2020). Overview of meta-analyses on giftedness. *Gifted and Talented International*, *35*(2), 110–127. https://doi.org/10.1080/15332276.2021.1893135
Opitz, A., Heene, M., & Fischer, F. (2017). Measuring scientific reasoning–a review of test instruments. *Educational Research and Evaluation*, *23*(3–4), 78–101. https://doi.org/10.1080/13803611.2017.1338586
Peter, M., Diekötter, T., & Kremer, K. (2019). Participant Outcomes of Biodiversity Citizen Science Projects: A Systematic Literature Review. *Sustainability*, *11*(10), 2780. https://doi.org/10.3390/su11102780
Prahmana, R. C. I. (2015). Hubungan Antara Keterampilan Meneliti dan Pembuatan Skripsi Mahasiswa Pendidikan Matematika. *Jurnal Numeracy*, *2*(2). https://doi.org/10.1017/CBO9781107415324.004
Rangkuti, A. N. (2016). Pembelajaran Berbasis Riset di Perguruan Tinggi. *Batusangkar International Conference*, *October 2016*, 141–152.
Retnawati, H., Apino, E., Kartianom, Djidu, H., & Anazifa, R. D. (2018). *Pengantar Analisis Meta*. Parama Publishing.

Rodríguez, G., Pérez, N., Núñez, G., Baños, J. E., & Carrió, M. (2019). Developing creative and research skills through an open and interprofessional inquiry-based learning course. *BMC Medical Education*, *19*(1), 1–13. https://doi.org/10.1186/s12909-019-1563-5

Roito, E., Solihat, R., & Wulan, A. R. (2019). Pencapaian Keterampilan Meneliti Abad Ke-21 Peserta Didik SMA pada Pembelajaran Ekosistem melalui Step-By-Step Model Experiment. *Assimilation: Indonesian Journal of Biology Education*, *2*(1), 14–18.

Sabirova, E. G., & Zakirova, V. G. (2015). Formation of Pupils' Research Skills in Informational and Educational Environment of Elementary School. *Procedia - Social and Behavioral Sciences*, *191*, 1139–1142. https://doi.org/10.1016/j.sbspro.2015.04.257

Sari, D. P., Wulan, A. R., & Solihat, R. (2019). Developing 21st century student research skills through assessment matrix and edmodo in biology project. *Journal of Physics: Conference Series*, *1157*(2). https://doi.org/10.1088/1742-6596/1157/2/022093

Smith, T. J., Lu, Y., Lin, H., Smith, T. J., & Hong, Z. (2020). The Effects of Critique- Driven Inquiry Intervention on Students ' Critical Thinking and Scientific Inquiry Competence. *Journal of Baltic Science Education*, *19*(1996), 954–971.

Solihat, R. et al. (2015). Keterampilan Riset Mahasiswa Biologi dan Pendidikan Biologi; Analisis Berdasarkan Refleksi Personal. *Metodik Didaktik*, *9*(2), 16–24.

Subekti, H., Setiawan, B., Yuhanna, Susilo, H., Ibrohim, & Suwono, H. (2018). Analisis Keterampilan Riset Mahasiswa Calon Guru IPA di Universitas Negeri Surabaya : Studi Eksplorasi. *Proceeding Seminar Nasional IPA IX*, *April*.

Torres, L. (2018). Research skills in the first-year biology practical - Are they there? *Journal of University Teaching and Learning Practice*, *15*(4).

Willison, J., & O'Regan, K. (2007). Commonly known, commonly not known, totally unknown: a framework for students becoming researchers. *Higher Education Research and Development*, *26*(4), 393–409. https://doi.org/10.1080/07294360701658609

Willison, J. W. (2012). When academics integrate research skill development in the curriculum. *Higher Education Research and Development*, *31*(6), 905–919. https://doi.org/10.1080/07294360.2012.658760

Willison, John W. (2018). Research skill development spanning higher education: Critiques, curricula and connections. *Journal of University Teaching and Learning Practice*, *15*(4).

Yalcin, M. N. A. (2015). Science teachers research skills through the use of scientific method: The case of Turkey. *Educational Research and Reviews*, *10*(17), 2439–2446. https://doi.org/10.5897/err2015.2308.