ASM Sc. J., 17, 2022

https://doi.org/10.32802/asmscj.2022.1173

Undergoing Science Experiment in Hybrid Learning

Nazihah Idris, Othman Talib*, Fazilah Razali, Haryati Kamaruddin and Nik Mawar Hanifah Nik Hassan

Faculty of Educational Studies, Universiti Putra Malaysia

Mastering in science concepts involves theoretical understanding and experimental scientific investigation. Students who do not master science process skills in science experiments comprehensively cannot solve problems related to the inquiry-discovery approach. Through hybrid learning, science experiments can also be conducted effectively. Hybrid learning is one cohesive learning experience that combines face-to-face and online mode learning. This concept paper identifies the positive impacts of the implementation of a science experiment in hybrid learning based on literature review. After the comprehensive review were made, findings show that through hybrid learning, hands-on science experiments can be performed at home with everyday materials and online support. Furthermore, undergoing hands-on science experiments in hybrid learning produces students who can identify, apply, and incorporate science concepts. In conclusion, hybrid learning becomes an alternative pedagogical method that follows the current needs towards increasing students' interest in exploring science phenomena. Empirical research regarding this topic can be conducted further about the effectiveness of undergoing science experiment by using hybrid learning practice.

Keywords: science experiment; hybrid learning; pedagogical method

I. INTRODUCTION

The rapid development of Industrial Revolution 4.0 in terms of technology applications has entailed improvements in pedagogy and learning infrastructure in the education system. The planning for a comprehensive, quality education system in line with the development of the 4.0 education revolution was carried out employing different initiatives (Camara, 2020). In the 4.0 industrial revolution era, an ecosystem of learning is no longer limited to the classroom and face-to-face learning. Ideally, students can study knowledge no matter where they are, while teachers can impart knowledge without attending the place of study. Innovation by assimilating hybrid learning is an alternative that integrates technology to allow the learning process to be implemented. Hybrid learning combines technology and innovation advancements with the interaction and involvement of conventional learning through an online and offline learning environment.

Science is a crucial subject for school students to master since it plays a vital part in everyday life Science is engaged in cooking, eating, breathing, playing, and so on; everything is the result of scientific advancement. Moreover, it is much more necessary to grasp scientific information in the technological environment we live in because scientific information has been regarded as being central for knowledge economy and intellectual development especially in emerging societies (Taştan *et al.,* 2018). Today's environment requires students to acquire both science concepts and their application for solving real-life issues. Therefore, science learning not only aims at the mastery of concepts alone but involves elements towards achievement in meaningful science experiments involving problem identification, creative and critical thinking skills, communication and collaborating in obtaining information. Understanding concepts in science experiments will produce a highly skilled workforce in research and innovation such as medicine, pharmacy, agriculture and microbiology (Sari *et*

*Corresponding author's e-mail: otalib@upm.edu.my

al., 2018). Correspondingly, science process and manipulative skills need to be reinforced and mastered by students through science experiments.

Efforts towards diversifying pedagogical methods for the implementation of science experiments should be undertaken. The implementation of science experiments in hybrid learning gives students space to explore scientific skills on their own more comprehensively. The objective of this paper is to identifies the positive impact of undergoing science experiment in hybrid learning. Thus, the research question for was, 'What are the positive impact of undergoing science experiment in hybrid learning?

II. LITERATURE REVIEW

A. Hybrid Learning

Hybrid learning is a learner-centred approach for acquiring information and skills that use an instructional design that incorporates digital (internet and mobile), printed, recorded, and conventional face-to-face class activities in a planned, practical pedagogical way (Jamison *et al.,* 2014). Hybrid learning aims to use the "old" and "new" forms of learning to improve the generated learning quality than face-to-face or online learning. Hybrid learning does not intend to substitute teachers' roles, but it aims to make learning effective happen as it is impossible to replace the role of teachers (Lestari *et al.,* 2021).

The delivery mode of hybrid learning can be divided into two categories which are synchronous and asynchronous activities. Synchronous activities occur in real-time with a group of students and a teacher online or in the classroom (Moorhouse & Wong, 2021). Traditional teaching in a school or classroom and video conferences, including two-way interaction between students and teachers, are examples of synchronous activities. The asynchronous online activity allows the teacher and students to interact about a lesson by meeting online on a specialised online platform. Meanwhile, synchronous online activities allow teachers and students to communicate in real-time, providing teacher-student and student-student engagement opportunities. As a result, students may constantly interact with the teachers and feel supported in completing any asynchronous work assigned to them (González-Lloret, 2020; Peachey, 2017).

Asynchronous activities in hybrid learning occur when the teacher and students are not present at the same time and there is no real-time contact. Thus, students can learn at their own pace using this type of activity. Referring to Amiti (2020), online learning is a type of asynchronous activity in which the teacher's and students' attendance is not linked. Students need flexibility; thus, online courses should be asynchronous and planned. Moreover, students and teachers require a familiar digital environment to communicate asynchronously and perform different learning activities such as uploading worksheets and materials, completing assignments, and evaluating students' progress (Moorhouse & Wong, 2021). While most asynchronous classes still have submission deadlines, students can interact with materials, peers, and teachers on their leisure, typically over a long period.

However, there are constraints of hybrid learning implementation when technological systems experience disruption during online synchronous learning occurs which causes students to lose motivation to focus and complete assignments (Sutisna & Vonti, 2020). However, this situation can be overcome creatively by teachers by recording learning sessions for reference by students asynchronously to allow students not to miss and make revision as reinforcement (Singaravelu, 2010), for example uploading video recordings through Google Classroom which is an asynchronous application that designed to support teaching and learning indefinitely by time and place, as long as the student environment has an internet network (Norhasliza Abdullah, 2020). Thus, a study from Rorimpandey and Midun (2021) stated that hybrid learning is one of the best learning models that can be used for students who are still adapting to the development of internet technology.

Other than that, Graham (2006) demonstrated that hybrid learning integrates learning methods that focus on an essential component which is designing. The designing methods comprise six elements (a) continuous classroom learning synchronously, (b) self-directed learning asynchronously, (c) application, (d) tutorial, (e) collaboration, and (f) evaluation and findings based on the procedure. The main objective of hybrid learning is to provide opportunities for the various characteristics of students to be independent, sustainable and make lifelong learning more effective, efficient, and engaging without losing the essence of conventional learning (Rosita *et al.,* 2019).

B. Science Experiment

Traditional teaching techniques are still used in the classroom, consuming time learning scientific concepts without creating their knowledge. Students are often passive, where learning is only a transfer of knowledge from teacher to student rather than a meaningful learning experience. As a result, science becomes a challenging and disagreeable subject for students (Nurlaely *et al.,* 2017). Students should be encouraged to engage in research and problem-solving activities to solve problems by designing an experiment that can verify a scientific concept and is proven up by data administered mathematically.

A science experiment is a test and a series of procedures done to confirm a hypothesis about a scientific concept or to advance information about an unknown scientific phenomenon (Ludwig *et al.,* 2021). Approaches to science experiments relate to students' minds-on and hands-on involvement in the planning and execution of science experiments (Chirikure, 2020). The integration of hands-on and minds-on learning is most successful in science experiments because it leads to higher student engagement and achievement levels, stimulates their curiosity, and cultivates an interest in lifetime learning (Irwanto *et al.,* 2019). A hands-on and minds-on approach in science experiments necessitates students undergoing scientific procedures, such as operating variables and making observations, as well as asking questions throughout the experiment.

Students can actively create knowledge (Škoda *et al.,* 2015), develop scientific reasoning and science process skills while witnessing how scientists work to generate scientific information through science experiments (George-Williams *et al.,* 2020). Science experiments actively encourage activity when students show an effort to highlight knowledge-seeking skills to satisfy their curiosity. These efforts involve processes of exploration, analysing data and drawing conclusions (Husni, 2020). Students actively participate in gaining new knowledge from experience while undergoing procedures for science experiments, making their own decisions, and accepting the consequences from their results in science experiments (Supriani *et al.,* 2019). Scientific reasoning refers to the cognitive processes performed in science experiments to reason about the substance of scientific concepts, particularly when generating and testing hypotheses, gathering evidence, and drawing conclusions (Díaz *et. al.,* 2021; Hidayah *et al.,* 2021).

Apart from that, Mamlok-Naaman *et al.* (2004) discovered that student attitudes toward science were impacted mainly by curiosity and emotion. They determined that students are unwilling to learn in a science class seriously if they find it uninteresting. These reasons may suggest that poor teaching instruction is the primary cause of low interest and unfavourable attitudes toward science learning in present schools' curricula worldwide. This happens because teachers focus on conceptual comprehension rather than science experiment implementation, limiting students' opportunity to investigate to prove their science knowledge. The issue with conceptual comprehension is that students find it challenging to link complicated scientific phenomena to real-life situations. This involves recognising new information, building explanations, and linking scientific phenomena (Widiyatmoko, 2018). For example, scientific phenomena regarding the need for photosynthesis and the need for seed germination. Students should compare and contrast the requirements for photosynthesis and seed germination, which are two completely different processes, by undergoing scientific experiments to make observations that reinforce conceptual understanding rather than simply memorising concepts alone.

In most previous studies, mentioning that implementation of science experiments is very important for learning science. However, labs with confined space remain a stumbling block for many schools. Due to shortages of equipment and materials, students have to experiment with many members per group. This conservative lab environment diminishes the learning of science process skills and restricts students' active participation. This situation caused students' involvement during the experiment not to occur comprehensively because the students underwent the experiment in groups, and the division of tasks occurred in rotation. Besides, there are also situations where there is a lack of cooperation among group members resulting in not all students fully participating in science experiments (Enneking *et. al.,* 2019; Ndihokubwayo, 2017; Wijayanti *et al.,* 2019).

III. SCIENCE EXPERIMENT AND HYBRID LEARNING

This concept paper discussed the implementation of science experiments in school by assimilating hybrid learning to enhance students' mastery in science learning. The discussion covers elements in hybrid learning, the importance of science experiments, the implementation of science experiments in hybrid learning and the significance of undergoing science experiments that students conduct in hybrid learning. Other than that, the application of science education in hybrid learning is closely related to science education pedagogy in line with the current developmental situation.

A. Importance of Undergoing an Experiment in Science Learning

Experiments in science foster discovery learning. The process of discovering new ideas is an essential element of learning science. Unfortunately, it is something that teachers are unable to provide for students. During their quest for knowledge, students must discover new ideas and concepts for themselves. Hands-on activities in science experiments also provide students with the opportunity to explore through trial and error. Students perform science experiments where they adopt alternatives, try things out in different settings, and learn what works and what does not. When students recognise they are working on incorrect concepts, they comprehend the fundamental ideas much better (Kim, 2018).

One of the most critical techniques for boosting student retention is to enhance students' enthusiasm and engagement in science experiments. Students are kept engaged in the science lessons via hands-on scientific experiments (Wiseman *et al.,* 2020). Compared to typical textbook science, students who participate in hands-on science experiments have a more favourable impression of science learning, more profound knowledge of scientific topics, and offer students the opportunity to learn by doing (Jackson & Mohr-Schroeder, 2018; Shana & Abulibdeh, 2020). Furthermore, science experiments encourage and increase students' interest in science and promote it as an exciting subject as they can make observations while undergoing science experiments. Students link their experience to the theories they learn when they make observations during science experiments and examine the results of their observations (Darmaji *et al.,* 2019). For example, performing science experiments related to yeast fermentation can provide a meaningful context in developing students' understanding of concepts of evidence rather than merely a readable theory.

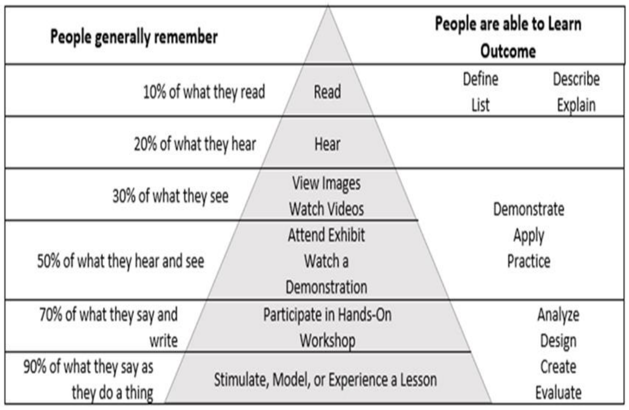

Figure 1. Edgar Dale's Cone of Experience (Dale, 1969)

Figure 1 above explains "The Edgar Dale Cone of Experience" that reflects the significance of students applying their knowledge (Dale, 1969). Dale cone of experience indicates that while selecting an instructional technique, it is essential to engage students to optimise their knowledge retention. The application of science experiments in science learning is aligned with Dale's learning cone because an experience in conducting hands-on experiments is more meaningful than just learning science concepts solely. Students remember 90% of what they "say and do" rather than what they read, hear, or see by undergoing hands-on experiments. Thus, it is possible to accomplish the goal of students becoming skilled in analysis, design and invention as a result of learning by doing a hands-on experiment (Chen *et. al.,* 2020; Rusmini *et. al.,* 2021; Shana & Abulibdeh, 2020).

Science process skills are fundamental to developing scientific knowledge acquired in science experiments and should be implemented among school students. Students utilise science process skills to examine the world around them and construct science concepts; thus, students must master these skills (Gultepe, 2016). Moreover, students' achievement in science subjects is correlated to mastery of science process skills in science experiments (Fang *et. al.,* 2016; Suryanti *et al.,* 2018).

B. Advantages of Hybrid Learning

Hybrid learning has advantages since it uses Information and Communication Technology (ICT), including mobile and non-mobile technologies as well as face-to-face instruction. For example, computer-assisted learning can increase the interactive and communicative elements of learning. Furthermore, the implementation of hybrid learning that integrates ICT offers free learning resources, open and flexible access to information to students in science learning (Fitriyana *et al.,* 2021).

Hybrid learning necessitates student-centred learning, with teachers contributing merely as sources of inspiration (Xu *et al.,* 2018). Students can also search the internet to answer scientific questions without the involvement of teachers. However, if the concept is challenging for students to implement, they should consult teachers or friends who have previously comprehended the concept. Questions can be posed when learning takes place either in the classroom or online. Students will be responsible for developing arguments to solve science problems. Subsequently, students can gain skills beyond their current capacities and broaden their problem-solving skills through hybrid learning.

Hybrid learning can ease teachers and be constructive for students because the learning can be done anywhere and whenever possible. Learning is not restricted to location or time since it is possible to learn everywhere and not necessarily in the classroom. Even at home, as long as there is a decent internet connection, the learning process may continue. Learning may also be done and accessible at any time of day or night, giving students more time to plan, prepare, and find answers to tasks assigned to them (Solikhin *et al.,* 2019).

Hybrid learning enables students to learn independently, more effectively and efficiently, also with greater accessibility to learning resources (Syafril *et al.,* 2021). Furthermore, hybrid learning encourages students to confidently try, learn from mistakes and explore on their own. This situation indirectly provides a meaningful experience in learning and increases their self-confidence.

C. Integration Science Experiment in Hybrid Learning through Synchronous and Asynchronous Activities

Generally, science homework given to students is monotonous and discourages students as it usually contains science concepts. However, students and parents love well-planned interactive assignments that help students progress and promote active learning through experiences, in which students rate the homework better than standard homework (Rosário *et. al.,* 2018; Van Voorhis, 2001). Giving tasks such as science experiments as homework will give students new learn by doing experience outside the classroom. This experience can occur through the implementation of science experiments in hybrid learning. The experience gained from the homework will enrich what has been learned at school by reinforcing scientific concepts and practices that have been introduced during school hours (Luehmann & Markowitz, 2007). The experience of conducting science experiments outside of school nurtures students to appreciate and instil interest in science knowledge through self-exploration done at home. This experience helps students understand the importance of science in their daily lives, the depth and scope of science as a field of knowledge.

Students increase their understanding of science and learn how to put up a method or procedure for testing and demonstrating science hypotheses by conducting their experiments through hybrid learning (Figure 2). Undergoing self-experiment at home and completing experiment reports are asynchronous activities in hybrid learning. Later, once students submit the experiment reports through the Google Classroom platform, a teacher would then access the work. The teacher utilises the self-marking function that provides direct feedback to students. Apart from that, teachers can conduct face-to-face or online learning sessions at set times for discussion sessions and presentations from students, based on results from the implementation of science experiments. This synchronous method allows the presence of teachers and students simultaneously, in which they should meet online on whatever platform is decided or meet face-to-face in the classroom.

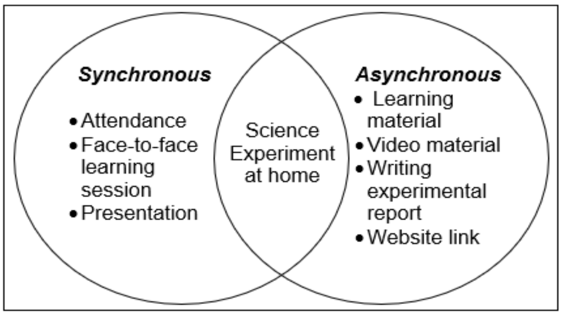

Figure 2. Hybrid learning environment model adapted from Eliveria *et al.* (2019)

D. Developing Self-Regulated Student

Also, Nidzam *et al.* (2010) argued that science experiments performed in the laboratory to confirm the theory and carried out at the level designated in the lesson plan do not allow students to generate and express their ideas. Consequently, students did not see the experiment as a requirement but rather a complement to their education. Thus, undergoing science experiments in hybrid learning allows students to explore by identifying the purpose of the experiment in a self-regulated manner. As a result, they can assess their skills, eager to embrace complex tasks, and see mistakes as opportunities to learn. Thus, self-regulated students are intrinsically driven to improve themselves and study deeply (Alvi & Gillies, 2020). This is supported by Kayacan and Ektem (2019) study, which reveals that self-conducted science experiments affect students' self-directed learning readiness. By developing self-directed learning readiness, students were encouraged to become active and responsible learners by self-exploring knowledge sources rather than relying entirely on the teacher.

Students who learn through self-regulated learning create their learning objectives and work to attain them. Whenever applicable, they explore alternative ways to attain their objectives. To achieve their objectives, students who manage their learning generally employ internal and not external motivation. They have great self-confidence since they know their abilities and regulate their learning without being forced (Landrum, 2020). Apart from that, Uyar (2015) discovered that by undergoing a self-science experiment in hybrid learning, students could enhance their learning process based on self-regulation according to the following points: a) a goal-oriented process exists, whereby students have their objective b) students take the initiative and work autonomously to attain the goal, implying that they accept accountability c) students are aware of the challenges required in the task, compensate for their levels to meet the task requirements and select strategies to accomplish the task; d) they pursue to complete the task with different strategies, namely, strategically action throughout the process e) they are highly motivated.

E. Enhancing Students in Science, Technology, Engineering, and Mathematics (STEM) Literacy

Incorporating STEM literacy in learning is one of the efforts to fulfil the demands of the 4.0 revolution period and prepare students ready to compete in a global work environment. STEM stands for "science, technology, engineering, and mathematics," all closely related fields of study. Technology and engineering are science applications, while science uses mathematics as a tool in data processing (Syukri *et al.,* 2021). STEM literacy is defined as students' capacity to recognise, apply, and integrate science, technology, engineering, and mathematics concepts to create and solve complex challenges. Moreover, applying the concept of literacy to disciplines individually and holistically results in an understanding of STEM literacy as a unique toolset for creating and using knowledge inside and across disciplines (Mohr-Schroeder, 2015). Integrated STEM literacy is based on the purposeful integration of two or would benefit from a creative solution integrating many disciplines (science, technology, engineering, and mathematics) focusing on real-world problem solving or designing an experiment (Sanders, 2009).

Students will be able to acquire STEM literacy directly when performing science experiments in a hybrid learning manner. STEM Literacy can be dissected based on integrating four elements, namely Science Literacy, Technology Literacy, Engineering Literacy and Mathematics Literacy. During the implementation of science experiments in hybrid learning at home, students earn four STEM literacy directly. Firstly, by acquiring science literacy based on mastery of knowledge and understanding of scientific concepts and using science process skills (Turiman *et al.,* 2012). Secondly, technological literacy is achieved when students can use and understand the suitability of technology applications as a facilitator in hybrid learning sessions. Students apply technology to search information as well as medium in a virtual learning session. Thirdly, engineering literacy can be attained when students design science experiments based on given problems and make a planning framework to obtain results in science experiments. Fourthly, mathematical literacy can be obtained in implementing science experiments when students integrate mathematics in recording data, analyse data based on computational formulas and interpret data based on mathematical principles (Zollman, 2012). Hence, STEM literacy is an outcome of the science experiment activities done by students in hybrid learning.

IV. DISCUSSION

Hybrid learning, especially in the subject of Science, is an initiative from teachers in developing students 'science knowledge through flexible learning sessions formally and informally and reducing students' dependence on teachers. Nevertheless, the science assignments given by teachers are mostly still in the form of homework assignments that test the cognitive element alone. Science is a discipline of knowledge that is practically oriented. Experiments are one of the core activities in science learning. Thus, the science experiment in hybrid learning is a manifestation of practical self-assignment to students not only for cognitive but also affective and psychomotor development.

In Malaysia, the re-implementation of the Practical Science Test as a centralised examination implemented in the Malaysian Certificate of Education examination taken by all fifth-form secondary school students in 2021 is an effort by the Examination Board in an effort to realise the aspirations of Malaysia Education Blueprint 2013-2025, which is to strengthen the foundation of science learning (MOE, 2020). Therefore, the study about the positive impacts of science experiment implementation in hybrid learning on its own was to identify the extent to which students' mastery of scientific skills and understanding of the concept of science occurs. This approach will be more impactful when students are able to conduct science experiment independently and master scientific skills that can strengthen the concept of science (Juhji & Nuangchalerm, 2020). Therefore, research on the implementation of science experiments in hybrid learning should be implemented to explore students' understanding of scientific skills.

V. CONCLUSION

Science experimentation is a learning technique that enables students to conduct investigations through preparation, implementation, and discussion. Learning becomes more effective in time management, saving the cost of using materials in the laboratory, and giving students space to explore hands-on independently in their free time according to their suitability outside of school hours by implementing science experiments in hybrid learning. Hybrid learning is a practicable educational pedagogy. Since hybrid learning involves fewer in-seat sessions than traditional face-to-face classes, students' time with their teacher is more valuable. As a result, a particular focus must be placed on producing quality use of that time. Future research on this topic should be conducted with a big sample size and at a variety of schools, including public and private educational institutions of all levels, in order to better generalise the findings.

VI. REFERENCES

Alvi, E & Gillies, RM 2020, 'Promoting self-regulated learning through experiential learning in the early years of school: a qualitative case study', European Journal of Teacher Education. doi: 10.1080/02619768.2020.1728739

Amiti, F 2020, 'Synchronous and Asynchronous E-Learning', European Journal of Open Education and E-Learning Studies, vol. 5, no. 2, pp. 60–70. doi: 10.46827/ejoe.v5i2.3313

Camara, JS 2020, 'Philippine Biology Education for a Curricular Innovation towards Industrial Revolution 4.0: A Mixed Method', Asian Journal of Multidisciplinary Studies, vol. 3, no. 1, pp. 41–51. www.paressu.org

Chang, Y., & Brickman, P. (2018). When group work doesn't work: Insights from students. *CBE Life Sciences Education*, *17*(3), 1–17. https://doi.org/10.1187/cbe.17-09-0199

Chen, JC, Huang, Y, Lin, KY, Chang, YS, Lin, HC, Lin, CY & Hsiao, HS 2020, 'Developing a hands-on activity using virtual reality to help students learn by doing, Journal of Computer Assisted Learning, vol. 36, no. 1, pp. 46–60. doi: 10.1111/jcal.12389

Chirikure, T 2020, 'Upper-secondary school students' approaches to science experiments in an examination driven curriculum context', Journal of Baltic Science Education, vol. 19, no. 4, pp. 523–535. doi: 10.33225/jbse/20.19.523

Dale, E 1969, Audiovisual Methods in Teaching, New York: Dryden Press.

Darmaji, D, Kurniawan, DA & Irdianti, I 2019, 'Physics education students' science process skills', International Journal of Evaluation and Research in Education, vol. 8, no. 2, pp. 293–298. doi: 10.11591/ijere.v8i2.28646

Díaz, C, Dorner, B, Hussmann, H & Strijbos, JW 2021, 'Conceptual review on scientific reasoning and scientific thinking', Current Psychology, April. doi: 10.1007/s12144-021-01786-5

Eliveria, A, Serami, L, Famorca, LP & Cruz, JSD 2019, 'Investigating students' engagement in a hybrid learning environment', IOP Conference Series: Materials Science and Engineering, vol. 482, no. 1, pp. 1–8. doi: 10.1088/1757-899X/482/1/012011

Fang, SC, Hsu, YS, Chang, HY, Chang, WH, Wu, HK & Chen, CM 2016, 'Investigating the effects of structured and guided inquiry on students' development of conceptual knowledge and inquiry abilities: a case study in Taiwan', International Journal of Science Education, vol. 38, no. 12, pp. 1945–1971. doi: 10.1080/09500693.2016.1220688

Fitriyana, N, Wiyarsi, A, Sugiyarto, KH & Ikhsan, J 2021, 'The Influences of Hybrid Learning with Video Conference and "Chemondro-Game" on Students' Self-Efficacy, Self-Regulated Learning, and Achievement toward Chemistry', Journal of Turkish Science Education, vol. 18, no. 2, pp. 233–248. doi: 10.36681/tused.2021.62

George-Williams, SR, Ziebell, AL, Thompson, CD & Overton, TL 2020, 'Inquiry-, problem-, context- and industry- based laboratories: an investigation into the impact of large-scale, longitudinal redevelopment on student perceptions of teaching laboratories', International Journal of Science Education, vol. 42, no. 3, pp. 451–468. doi: 10.1080/09500693.2020.1714788

González-Lloret, M 2020, 'Collaborative tasks for online language teaching', Foreign Language Annals, vol. 53, no. 2, pp. 260–269. doi: 10. 1111/ flan. 12466

Graham, CR 2006, Blended Learning System: Definition Current trends, And Future Direction. In CJ Bonk & CR Graham (Eds), Handbook of blended learning: global perspective, local design (pp.3-12). San Fransisco, CA: Pfeiffer

Gultepe, N 2016, 'High School Science Teachers' Views on Science Process Skills', International Journal of Environmental and Science Education, vol. 11, no. 5, pp. 779–800. doi: 10.12973/ijese.2016.348a

Hidayah, Y, Dewi, DA & Trihastuti, M 2021, 'The adaptation of scientific reasoning of prospective teachers for primary education in the perspective of civic science', Jurnal Civics: Media Kajian Kewarganegaraan, vol. 18, no. 1, pp. 1–9. doi: 10.21831/jc.v18i1.36916

Husni, H 2020, 'The Effect of Inquiry-based Learning on Religious Subjects Learning Activities: An Experimental Study in High Schools', Jurnal Penelitian Pendidikan Islam, vol. 8, no. 1, p. 43. doi: 10.36667/jppi.v8i1.434

Irwanto, Saputro, AD, Rohaeti, E & Prodjosantoso, AK 2019, 'Using inquiry-based laboratory instruction to improve critical thinking and scientific process skills among preservice elementary teachers', Eurasian Journal of Educational Research, 2019(80), pp. 151–170. doi: 10.14689/ejer.2019.80.8

Jackson, CD & Mohr-Schroeder, MJ 2018, 'Increasing Stem Literacy Via an Informal Learning Environment', Journal of STEM Teacher Education, vol. 53, no. 1. doi: 10.30707/jste53.1jackson

Jamison, A, Kolmos, A & Holgaard, JE 2014, 'Hybrid Learning: An integrative approach to engineering education', Journal of Engineering Education, vol. 103, no. 2, pp. 253–273. doi: 10.1002/jee.20041

Juhji, J & Nuangchalerm, P 2020, 'Interaction between scientific attitudes and science process skills toward technological pedagogical content knowledge', Journal for the Education of Gifted Young Scientists. doi: 10.17478/jegys.600979.XX

Kayacan, K & Ektem, IS 2019, 'The effects of biology laboratory practices supported with self-regulated learning strategies on students' self-directed learning readiness and their attitudes towards science experiments', European Journal of Educational Research, vol. 8, no. 1, pp. 313–323. doi: 10.12973/eu-jer.8.1.313

Kim, M 2018, 'Understanding children's science identity through classroom interactions', International Journal of Science Education, vol. 40, no. 1, pp. 24–45. doi: 10.1080/09500693.2017.1395925

Landrum, B 2020, 'Examining students' confidence to learn online, self-regulation skills and perceptions of satisfaction and usefulness of online classes', Online Learning Journal, vol. 24, no. 3, pp. 128–146. doi: 10.24059/olj.v24i3.2066

Lestari, Syafril, S, Latifah, S, Engkizar, E, Damri, D, Asril, Z & Yaumas, NE 2021, 'Hybrid learning on problem-solving abiities in physics learning: A literature review', IOP Conference Series: Earth and Environmental Science, vol. 1796, no. 1. doi: 10.1088/1742-6596/1796/1/012021

Ludwig, T, Priemer, B & Lewalter, D 2021, 'Assessing Secondary School Students' Justifications for Supporting or Rejecting a Scientific Hypothesis in the Physics Lab', Research in Science Education, vol. 51, no. 3, pp. 819–844. doi: 10.1007/s11165-019-09862-4

Luehmann, AL & Markowitz, D 2007, 'Science Teachers' perceived benefits of an out-of-school enrichment programme: Identity needs and university affordances', International Journal of Science Education, vol. 29, no. 9, pp. 1133–1161. doi: 10.1080/09500690600944429

Mamlok-Naaman, R, Ben-Zvi, R, Hofstein, A, Menis, J & Erduran, S 2004, Mamlok-Naaman, R, Ben-Zvi, R, Hofstein, A, Menis, J & Erduran, S 2005, 'Influencing Students' Attitudes towards Science by exposing them to a Historical Approach', International Journal of Science and Mathematics Education, 3(May).

MOE 2020, Surat Pekeliling Ikhtisas KPM Bilangan 2 Tahun 2020: Pelaksanaan Ujian Amali Sains Bagi Mata Pelajaran Fizik, Kimia, Biologi Dan Sains Tambahan Peperiksaan Sijil Pelajaran Malaysia Mulai Tahun 2021. https://www.moe.gov.my/en/pemberitahuan/announcement/spi-kpm-bil2-2020

Mohr-Schroeder, MJ 2015, STEM Education: Understanding The Changing Landscape. In A Practice-Based Model of STEM Teaching: STEM Students on the Stage (SOS) (Issue May 2016). doi: 10.1007/978-94-6300-019-2

Moorhouse, BL & Wong, KM 2021, 'Blending asynchronous and synchronous digital technologies and instructional approaches to facilitate remote learning', Journal of Computers in Education, 0123456789. doi: 10.1007/s40692-021-00195-8

Nidzam, C, Osman, K & Halim, L 2010, 'Hubungan Ramalan Persekitaran Pembelajaran Makmal Sains dengan Tahap Kepuasan Pelajar', vol. 35, no. 2, pp. 19–30.

Norhasliza Abdullah 2020, 'Persepsi Pelajar Terhadap Penggunaan Google Classroom Sebagai Media E-Pembelajaran Dalam Kursus Penyelidikan Pendidikan-Kertas Projek', Jurnal Penyelidikan Pendidikan, vol. 21, pp. 69–82.

Nurlaely, N, Permanasari, A & Riandi, R 2017, 'Student's STEM Literacy in Biotechnology Learning at Junior High School', Journal of Physics: Conference Series, vol. 895, no. 1. doi: 10.1088/1742-6596/895/1/012155

Peachey, N 2017, 'Synchronous online teaching', in M Eds Carrier, RM Damerow & KM Bailey (Eds.), Digital language learning and teaching. New York: Routledge.

Prabha, S. (2016). Laboratory Experiences for Prospective Science Teachers: A Meta-analytic Review of Issues and Concerns. *European Scientific Journal*, *12*(34), 235–250.

Rorimpandey, WHF & Midun, H 2021), 'Effect of Hybrid Learning Strategy and Self-Efficacy on Learning Outcomes', Journal of Hunan University Natural Science, vol. 48, no. 8,pp.181–189. http://jonuns.com/index.php/journal/article/view/672

Rosário, P, Carlos Núñez, J, Vallejo, G, Nunes, T, Cunha, J, Fuentes, S & Valle, A 2018, 'Homework purposes, homework behaviors, and academic achievement. Examining the mediating role of students' perceived homework quality', Contemporary Educational Psychology, vol. 53, pp. 168–180. doi: 10.1016/j.cedpsych.2018.04.001

Rosita, N, Saun, S & Mairi, S 2019, 'Google Classroom for Hybrid Learning in Senior High School', in Journal of Learning and Teaching in Digital Age.

Rusmini, Suyono, & Agustini, R 2021, 'Analysis of Science Process Skills of Chemical Education Students Through Self-Project Based Learning (SJBL) in the COVID-19 Pandemic Era', Journal of Technology and Science Education, vol. 11, (January 2020), pp. 371–387. doi: https://doi.org/10.3926/jotse.1288

Sanders, M 2009, 'STEM, STEMEducation, STEMmania', The Technology Teacher, pp. 20–27. https://vtechworks.lib.vt.edu/bitstream/handle/10919/51616/STEMmania.pdf?sequence=1&isAllowed=y

Sari, U, Alici, M & Sen, ÖF 2018, 'The Effect of STEM Instruction on Attitude, Career Perception and Career Interest in a Problem-based Learning Environment and Student Opinions', Electronic Journal of Science Education, vol. 22, no. 1, pp. 1–21.

Shana, Z & Abulibdeh, ES 2020, 'Science practical work and its impact on students' science achievement', Journal of

Technology and Science Education, vol. 10, no. 2, pp. 199–215. doi: 10.3926/JOTSE.888

Singaravelu, G 2010, 'Hybrid Learning In Enhancing Communicative Skill In English', I-Manager's Journal of Educational Technology. doi: 10.26634/jet.7.1.1175

Škoda, J, Doulík, P, Bílek, M & Šimonová, I 2015, 'The effectiveness of inquiry based science education in relation to the learners´ motivation types', Journal of Baltic Science Education, vol. 14, no. 6, pp. 791–803.

Solikhin, F, Sugiyarto, KH & Ikhsan, J 2019, 'The Impact Of Virtual Laboratory Integrated Into Hybrid Learning Use On Students' Achievement', Jurnal Ilmiah Peuradeun, vol. 7, no. 1, January 2019, pp. 81-94.

Supriani, Y, Fardillah, F, Rmudi, T & Herman, T 2019, 'Developing Students' Mathematical Justification Skill Through Experiential Learning', Journal of Physics: Conference Series, vol. 1179, no. 1. doi: 10.1088/1742-6596/1179/1/012070

Suryanti, Ibrahim, M & Lede, NS 2018, 'Process skills approach to develop primary students' scientific literacy: A case study with low achieving students on water cycle', IOP Conference Series: Materials Science and Engineering, vol. 296, no. 1. doi: 10.1088/1757-899X/296/1/012030

Sutisna, E & Vonti, LH 2020, 'Innovation Development Strategy for Hybrid Learning', Journal of English Education, vol. 9, no. 1, pp. 103–114.

Syafril, S, Latifah, S, Engkizar, E, Damri, D, Asril, Z & Erlina, N 2021, Hybrid learning on problem-solving abiities in physics learning : A literature review Hybrid learning on problem-solving abiities in physics learning : A literature review. doi: 10.1088/1742-6596/1796/1/012021

Syukri, M, Yanti, DA, Mahzum, E & Hamid, A 2021, 'Development of a PjBL Model Learning Program Plan based on a STEM Approach to Improve Students' Science Process Skills', Jurnal Penelitian Pendidikan IPA, vol. 7, no. 2, p. 269. doi: 10.29303/jppipa.v7i2.680

Taştan, SB, Davoudi, SMM, Masalimova, AR, Bersanov, AS, Kurbanov, RA, Boiarchuk, AV & Pavlushin, AA 2018, 'The impacts of teacher's efficacy and motivation on student's academic achievement in science education among secondary and high school students', Eurasia Journal of Mathematics, Science and Technology Education, vol. 14, no. 6, pp. 2353–2366. doi: 10.29333/ejmste/89579

Turiman, P, Omar, J, Daud, AM & Osman, K 2012, 'Fostering the 21st Century Skills through Scientific Literacy and Science Process Skills', Procedia - Social and Behavioral Sciences, vol. 59, pp. 110–116. doi: 10.1016/j.sbspro.2012.09.253

Uyar, Y 2015, Development of self regulated reading skills and its impact on comprehension (Unpublished doctorate thesis). Gazi University, Ankara, Turkey.

Van Voorhis, FL 2001 'Interactive Science Homework: An Experiment in Home and School Connections', NASSP Bulletin, vol. 85, no. 627, pp. 20–32. doi: 10.1177/019263650108562703

Widiyatmoko, A 2018, 'The Effectiveness of Simulation in Science Learning on Conceptual Understanding: A Literature Review', Journal of International Development and Cooperation, vol. 24, no. 1・2, pp. 35–43. doi: 10.15027/45251

Wiseman, E, Carroll, DJ, Fowler, SR & Guisbert, E 2020, 'Iteration in an Inquiry-Based Undergraduate Laboratory Strengthens Student Engagement and Incorporation of Scientific Skills', Journal of the Scholarship of Teaching and Learning, vol. 20, no. 2, pp. 99–112. doi: 10.14434/josotl.v20i2.26794

Xu, J, Yang, HH & MacLeod, J 2018, 'STEP on connected classroom climate in a hybrid learning environment', International Journal of Innovation and Learning, vol. 23, no. 4, pp. 430–443. doi: 10.1504/IJIL.2018.092037

Zollman, A 2012, 'Learning for STEM Literacy: STEM Literacy for Learning', School Science and Mathematics, vol. 112, no. 1, pp. 12–19. doi: 10.1111/j.1949-8594.2012.00101.x