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Scientific Work Independence Application for Various Education Levels Referring to Piaget's Theory to Support the Implementation of Science Integrated Learning Model

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Abstract

The research specifically aims to create an application of scientific work independence instruments through Science Integrated Learning (SIL) for various education levels (primary, secondary, tertiary). The SIL model is applied in learning to find specific indicators for scientific work independence following students' development. This study applied the Research and Development methodology. Product testing was conducted in elementary schools, junior high schools, senior high schools, and universities. Based on the research results, SIL V1.0 App is a software developed based on mobile apps in the form of an Android application that is installable on a device with Android OS as the operating system. The application is named SIL V1.0 Apps, an acronym for Science Integrated Learning Application. The scientific work independence instrument developed by referring to Piaget's theory has a characteristic where the level of independence at each stage of scientific work is based on the development of children's learning psychology. Scientific work independence application at various education levels, which refers to Piaget's Theory, has more precise boundaries because it is adjusted to children's psychological development. The difference in learning independence level occurs because of the age difference.

Keywords: Application, Independence, Piaget's Theory, Science Integrated Learning

INTRODUCTION

Educational innovation in the digital era requires application products with high applicability to strengthen the application of technology in learning. Education at various levels is facilitated by various applications so that the distance between educators and students does not constrain learning. Application products are considered to have high applicability in learning if they have advantages similar products do not have, are easy to use, and their specifications meet the needs (Muhammad et al., 2021; Nouwen et al., 2022). The products developed are not only used in learning but also have the opportunity to become products of economic value. A product developed in education can have economic value or generate income if users have a high interest because the product is a solution to learning problems (Hollands & Escueta, 2020). Innovative learning products have a wide range of applications at various levels of education (primary, secondary, and tertiary) and follow children's learning needs.

Children have different learning needs due to age differences. Piaget's theory emphasizes that children's cognitive skills develop gradually at different age ranges. Forcing learning activities on children is not per this theory because it can potentially disrupt children's psychological development (Stoltz, 2018 & Winstanley, 2021). Children's way of thinking differs according to age. Qualitatively, children are different from adults. Piaget mentioned several stages of the development of children's intellectual skills. Different stages of child development affect the ability to understand knowledge. The application of learning theory to determine the standard of children's abilities is needed so that age-appropriate learning needs can be mapped.

Analysis of the findings in articles published in reputable international journals and analysis of preliminary studies have been carried out. The research problem formulation is how to apply scientific work independence at the primary, secondary, and tertiary education levels through integrated science learning. There is an urgent need for standardization of the measurement of scientific work independence. Scientific work requires standardized criteria to determine readiness to make discoveries in science learning (Parmin et al., 2017 & Wei et al., 2021). Indicators of scientific work independence are developed from the difficulty of discovery in science which is adjusted to the level of education. The ability to do scientific work is easier to observe in learning that applies strategies oriented to scientific work (Plaisance et al., 2021). The learning model with the syntax of scientific work independence was chosen to be applied to train scientific work independence.

The research specifically aims to make application products of scientific work independence instruments through Science Integrated Learning (SIL) for various education levels (primary, secondary, tertiary). The product is developed regarding the different learning independence levels following the children's way of learning. The SIL model is applied in learning to find specific indicators for scientific work independence following students' development. The research also aims to find the standard application of scientific work independence instruments for various levels of education. This research product is targeted to have high applicability that can be commercialized.

Measurement of scientific work independence is needed in science learning. Based on preliminary and article study results, standardization of scientific work independence instruments is urgent to develop through research. The research was conducted to make a product in the form of a scientific work independence instrument appropriate at the primary, secondary, and tertiary education levels through application programs. A research flow is drawn for the product development process to have high applicability and the potential to be commercialized, as in Figure 1.

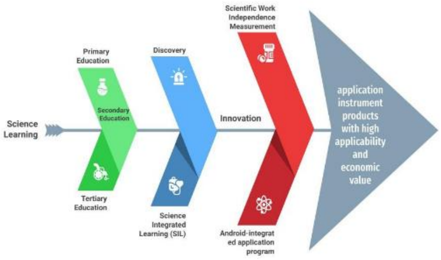

Figure 1. Research Flow

Learning innovation in the research flow aligns with the road map developed by LP2M Universitas Negeri Semarang. Learning innovations with applicable information technology will be achieved in 2022 to support the achievement of prospective science teachers' competence. The primary, secondary, and tertiary science learning analysis was carried out to measure students' scientific work independence. Scientific work independence is very much needed in face-to-face and online science learning through discovery activities in the laboratory and outdoor. Preliminary research and literature studies have not found a standard instrument for scientific work independence appropriate to education levels. The SIL model is used because it has learning activities in all syntaxes oriented to scientific work independence. The SIL model can be applied to various education levels by modifying the learning difficulties. Mapping of students' learning activities will specifically be observed with the application of a learning model (Chhabra & Warn, 2019; Kopper et al., 2020; Ke & Chang, 2021).

Novelty value learning innovations in this study are new products in the form of scientific work independence instruments at different levels of education. Products are developed digitally using the Android-integrated application program. The results of the development in this study are not limited to learning, but because of the urgent need with a broad target audience, the product is expected to have economic value. The final product is a guidebook with ISBN and copyright. The product will be disseminated through the Perkumpulan Pendidik IPA Indonesia (PPII) professional organization. This organization is a strategic partner in this research because it has a network of cooperation between science education study programs at the undergraduate, postgraduate, and doctoral levels. It comprises teachers and lecturers from primary, secondary, and tertiary education levels.

Science or natural science is studied from elementary to secondary to tertiary education. Both face-to-face and online modern science learning require strengthening scientific work independence. Science learning cannot be limited to ordinary scientific work and needs an independence-oriented scientific process. Students can carry out face-to-face or online learning, requiring independent scientific activities that utilize the surrounding environment as a laboratory. Scientific work independence in science is adjusted to students' level of development and is required in an integrated manner (Parmin et al., 2016; Wei, 2020 & Roehrig et al., 2021). The preliminary study analyzed the assessment of scientific work in schools through discussions with the Perkumpulan Pendidik IPA Indonesia (PPII) administrators and found that scientific work independence was assessed using different instruments. Science teachers and lecturers are different in applying the indicators and methods of measuring scientific work independence they understand.

Digitization of science learning tools is needed because science's dynamic nature requires applicable tools. Science learning tools presented with information technology provide easy access so that learning is no longer limited by distance and time (Yeh et al., 2019; Abdullah et al., 2021). The application of science learning instruments can implement existing application programs by considering high applicability (Rapanta et al., 2021). The main consideration in developing application products is done after analyzing similar products. The development of instruments integrated with Android devices has the advantage of being easy to operate, attractive, and interactive (Buluma & Walimbwa, 2021; Pumptow & Brahm, 2021; & Papastergiou & Mastrogiannis, 2021). Applications that can be used in developing learning products must be easy to operate on mobile apps in the form of Android applications (Ünver & Bakour, 2020; Syaifudin et al., 2021). Each science has its characteristics, so it must be adjusted to develop learning application products. Science as a scientific field emphasizes the discovery process through scientific work activities. Essential applications are developed to make it easy to get accurate data.

Scientific work independence was developed from the concept of learning independence by Pannen (2001), where students carry out learning activities independently by utilizing various existing learning resources to achieve learning goals. Scientific work independence is scientific work carried out in in-door and outdoor laboratories in science learning (Parmin et al., 2017). Learning theory becomes a construction in measuring differences in learning independence based on students' psychological development (Tahar & Enceng, 2006). Various literature studies found that implementing learning independence in primary education still requires a prominent teacher role in guiding scientific work activities. In learning activities in secondary schools, the role of teachers in guiding scientific work has begun to be reduced. In contrast, lecturers have a small role in students' scientific work at the tertiary education level.

Characteristics of students at the primary, secondary, and tertiary education levels are different due to age and learning methods. The characteristics of students at the primary education level in learning science are still highly dependent on the teacher (Nguyen et al., 2021). At the secondary education level, students' curiosity about science is developing when learning, so they begin to use various learning resources independently but still need the role of the teacher (Romine et al., 2017). Skills in utilizing various learning resources through discovery activities encourage students to develop independent learning (Ceglie & Settlage, 2016). Different ways of learning require learning tools tailored to the level of education so that the knowledge possessed is tiered and interrelated. The selection of learning strategies with room for educators to change the learning experience in stages can be used as continuous learning activities.

A science learning strategy with scientific work independence activities that can be adapted to students' development level is the Science Integrated Learning (SIL) Model. The SIL model has a syntax that includes exploration, concept integration, experimentation, analysis, action taking, and reflection. The advantage of the SIL model is that it has learning activities in all syntaxes oriented to scientific work independence. Implementing the SIL Model on primary school students' learning independence still needs assistance from the teacher (Kurniawan et al., 2021). Applying the SIL Model to high school students impacts students' skills in finding solutions to the problems in learning (Qoeroti et al., 2018). The main disadvantage of research that applies the SIL model is that it does not yet have a standardized instrument for measuring scientific work independence for all education levels.

Applicative, easy-to-use, and interesting learning tools can be developed using application programs. Combining online form provider applications like Jotform or Google Forms will produce a digital application. Learning product applications are easy to implement when integrated through Android (García-Peñalvo & Conde, 2015; Trabelsi et al., 2017). Digital products to develop educational instruments can use various existing application programs (Lin & Miettinen, 2019). The development of instruments that will be integrated into mobile devices needs to consider interesting and interactive features. Instruments developed with information technology have easy access for distribution through communication networks and even social media (Papadakis et al., 2021). The development of scientific work independence instruments uses application programs to be easily accessed by users.

Piaget's theory underlies the development of criteria for the level of independence of scientific work. This theory builds knowledge according to the development of students based on age. Different levels of education make the level of independence of scientific work different. This theory is used because of the relationship between children's scientific work independence and age. Age differences cause children's learning needs to differ, so the demands of learning activities cannot be equated (Piaget, 1954; Bergling, 1999). The theoretical framework is built on the difference in the maturity of children's thinking—the more mature the way of thinking, the more independent the children's ability in scientific work. The scientific work independence is built from the concept of independent learning. Children with independence in learning are driven by curiosity.

Information processing theory becomes a reference in building a theoretical framework because knowledge will be more readily transferred when there is a desire to understand what is being taught (Lamnina & Chase, 2021). The importance of independent scientific work must be considered because of the learning conditions that sometimes have to be forced to occur fully online, online and face-to-face combined, and fully face-to-face. Science concepts are easy to teach, but practical skills from scientific work cannot be learned like scientific theories. The basic theory of learning science is a combination of theory and practice. The truth of science is more easily conveyed through practical results (van Diggelen et al., 2021).

METHOD

This study applied the Research and Development methodology referring to Borg and Gall (1989). The method has detailed stages, so it is suitable for developing new products with high applicability at the primary, secondary, and tertiary education levels. This design was chosen because it has the function of developing selective learning tools and has easy steps to implement. The research stages include preliminary studies, research planning, design development, small-scale product testing, revision of small-scale test results, large-scale product testing, revision of large-scale test results, dissemination, and implementation of the final product.

The preliminary study was conducted by analyzing the assessment of the scientific work independence by teachers and lecturers in learning science at each level of education. The exploration of the preliminary study was carried out by analyzing various research findings published in journals. Research planning was arranged from the preliminary study by preparing the equipment needed for product development. Design development is carried out by analyzing existing initial products for testing new products.

Small-scale product testing was conducted on ten students in elementary, junior high, and senior high schools and ten students in colleges. Large-scale product testing was conducted on four different target groups. The four target groups for the large-scale trial were fifth graders of elementary school, eighth graders of junior high school, eleventh graders of high school, and science education students. All large-scale product testing targets are in Semarang City, considering costs, time, and the pandemic situation. Product development involved science learning evaluation experts and information technology experts in learning to validate products. Dissemination and implementation of products on a wide scale involved PPII.

The scientific work independence application instrument created and developed is based on mobile apps in the form of an Android application that is installable on a device with Android OS as the operating system. This application is named KEJALI Apps, an acronym for *Kemandirian Kerja Ilmiah Aplikasi*. As a design concept for developing KEJALI Apps, a choice of education levels developed through Science Integrated Learning is available on the home page. Each level of education will be developed using an online form provider application such as Jotform or Google Form and then bundled into one complete application known as KEJALI Apps.

The scientific work independence instrument was validated from the assessments of education evaluation experts, science education experts, and learning application program development experts. Data on the applicability of scientific work independence instruments are at three levels of education. Students' scientific work independence was analyzed using a descriptive technique by calculating each group's average score, which was presented as a graph of the level of scientific work independence.

RESULTS AND DISCUSSION

Results from the Word Association Test

The developed application integrated into Android has five features. The display of the developed application is shown in Figure 2.

Figure 2. Application Display

The advantages of the developed application are presented in Table 1.

Table 1. The Advantages of the Application

Application Component	Indicator
Readability	The system created has an easy-to-read work independence application feature.
Ease of use	The app is easy to use.
User requirement server hosting	User requirement server hosting from the website meets the standards.
Service evaluation	The resulting service evaluation system is easy to understand.
Variable	The resulting application system has the appropriate variables.
System speed	The system is fast in processing.
Application accuracy	The application accuracy meets the standards.
Understanding of the application by the user	Users generally understand the resulting application.
Constant stability	The application works stably every time.
Use of Android devices	The application is available to use on Android devices.
Informative for users	The resulting application can provide information to users well.
Application design standard	The application system created is per application design standards.
Display design	The application display design follows user needs.

The results of developing scientific work independence in elementary schools, junior high schools, high schools, and universities to support the implementation of the integrated learning science model are shown in Figure 3.

The results of scientific work independence measurements through science learning for students in elementary, junior high, senior high, and universities are shown in Figure 4.

Dominantly, students in elementary schools are still assisted by teachers in scientific work activities. The involvement of teachers begins to decrease at the junior secondary education level and so on until tertiary education.

SIL V1.0 App is a software developed based on mobile apps in the form of an Android application that is installable on a device with Android OS as the operating system. The application is named SIL V1.0 Apps, an acronym for Science Integrated Learning Application. As a development design concept, the home page of SIL V1.0 Apps presents an opening screen. Then on the next screen, there are five menu choices about SIL, elementary schools, junior high schools, senior high schools, and universities. Each level of work independence evaluation developed through SIL will be developed using the Google Form. The evaluation results of students' work independence are stored on the Android server. The resulting Android application is simple and easy to access.

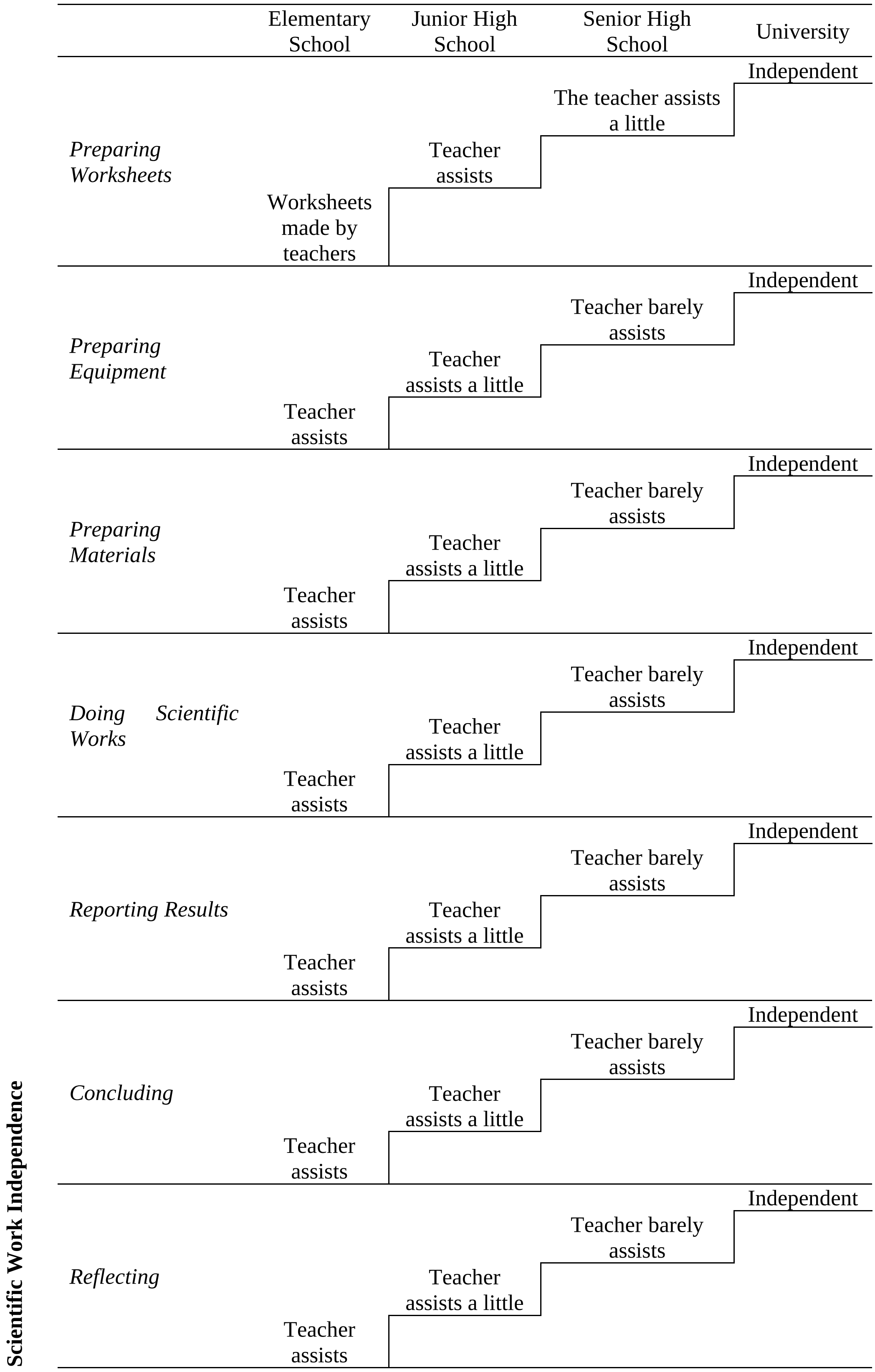

Figure 3. Level of Scientific Works Independence

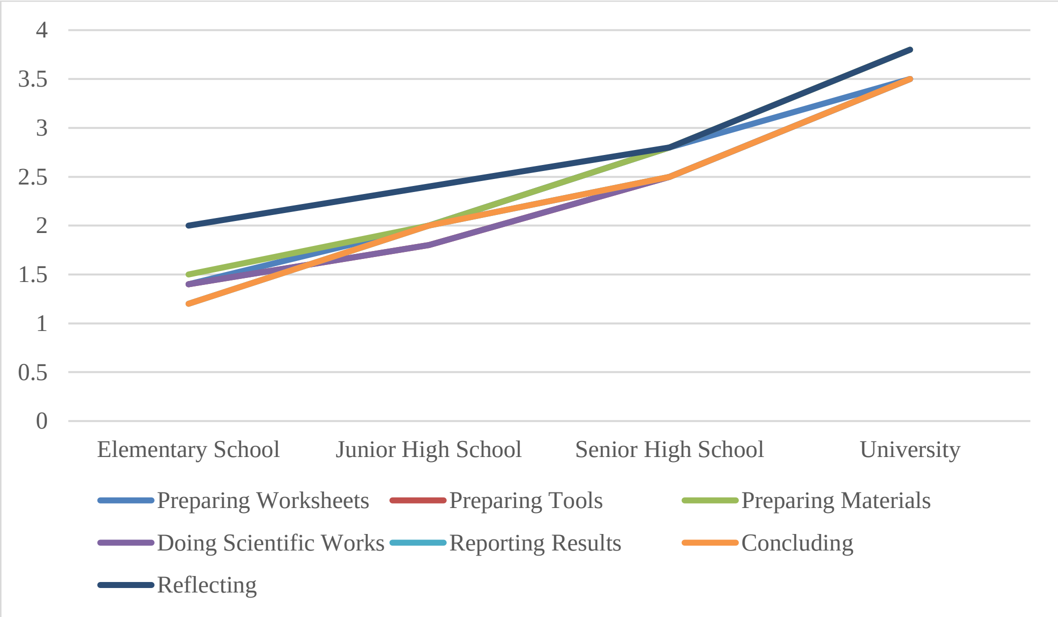

Figure 4. Level of Scientific Work Independence

Installing it on Android allows users to enjoy scientific work independence application services. Applications developed in learning activities can be used widely when easily accessible and have content under the needs (Broadbent et al., 2020; Jeon, 2022).

Scientific work in the form of practices for elementary school students is difficult or impossible to carry out during online learning. Students at the primary education level are still entirely dependent on the teacher when preparing practice materials, implementing, reporting, and reflecting. Piaget's learning theory explains that, at the age of 7 to 12, logical thinking begins to develop only in physical objects (Costa, 2019; Winstanley, 2022; Liang & Dong, 2022). At this age, children cannot yet solve problems independently. Practice is a learning activity that requires skills to apply systematic work procedures, so elementary school-age children cannot practice alone without being accompanied by a teacher. The students' scientific work independence at this basic level requires full assistance from the teacher. In online learning, teachers are not present in person, so learning science through scientific activities requires innovation in practice activities (Nighojkar et al., 2021; Abdull Mutalib & Jaafar, 2022; Sistermans, 2020). The form of innovation teachers can choose is to simulate practice through video shows, and students follow work procedures from the results of listening to video shows. Practical independence in 7 to 12-year-old children in face-to-face learning can be developed by giving children the opportunity to try in every stage of practice.

Children aged 12 years and above can think abstractly by manipulating ideas without relying on concrete manipulation. Curiosity in children aged 12 years and above impacts the desire to try. Providing opportunities to learn by learning can foster an urge to study science seriously in children (Alghamdi & Malekan, 2020; Wan, 2021). Teachers in junior high schools can take advantage of children's desire to try through practice. Assistance must still be given because sometimes the desire to try children is not followed by an attitude of prudence. Teachers must begin to give roles to children to foster scientific work independence. The age factor developed by various exercises to carry out scientific work stages independently can be carried out for the stages of preparing materials and tools, practicing, compiling reports, reporting, and even reflecting. Compiling their practice worksheets is still impossible for children aged 12 years and over in scientific work, so the task is still under the teacher's authority. Providing opportunities and trust for children to do independently impacts children's confidence to do scientific work.

Scientific work independence begins to appear strong in children aged 14 years and above. Indonesian children at this age are in high school. With a bit of guidance from the teacher, children of this age can carry out scientific works. At the age of 12 years, children have not been able to compile practical worksheets, but children aged 14 years and above can be given the authority to develop. The role of the teacher is enough to provide practice goals, and children can already prepare supporting tools to reflect on their own with a bit of help from the teacher. The psychology of children who have gone through the phase of trying out of intense curiosity at 12 can be developed by providing opportunities to explore their abilities. The ability to recognize self-strength in learning is grown to carry out discovery activities in science learning (Lu et al., 2022). The encouragement to do scientific work independently requires motivation from the teacher so that children are confident of finding something from the practice.

Students can fully implement the SIL model syntax in universities. Lecturers explain the purpose of scientific work, and students with mature ways of thinking can translate them into worksheets. The freedom of scientific work given to students is not limited to testing the truth of concepts but can be directed to discoveries (Naidoo, 2017). Psychologically, students can think complexly to develop a plan of discovery from studying various literature. Learning science online or face-to-face is not an obstacle for students unless practices require laboratory equipment unavailable outside the laboratory. The courage of lecturers in providing broad opportunities for students to work independently is an essential capital in preparing competent college graduates.

CONCLUSION

Scientific work independence application for various education levels, which refers to Piaget's Theory, has more precise boundaries because it is adjusted to children's psychological development. The difference in learning independence level occurs because of the age difference. The application of the SIL model, which has a learning orientation to scientific work independence, needs to be adjusted to the children's psychological development. An important strategy from educators so that children's scientific work independence grows and develops is to provide opportunities and confidence to try during learning activities.

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