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HOW CAN TPACK SUPPORT THE STATISTICAL LITERACY SKILLS OF MATHEMATICS STUDENTS' TEACHERS?

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Abstrak

Perkembangan TIK pada revolusi industry 4.0 sangat cepat dan tak terbatas, menyebabkan pentingnya literasi statistik bagi mahasiswa calon guru matematika sebagai global citizen serta calon guru matematika dimasa mendatang untuk dapat menginterpretasi, mengkritisi suatu informasi sebelum mengkomunikasikannya dalam beragam macam media. Penelitian ini bertujuan mendeskripsikan *Technological Pedagogical Content Knowledge* (TPACK) dalam mendukung kemampuan literasi statistik mahasiswa calon guru matematika. Metode dalam penelitian ini adalah *design research* tipe *validation study* untuk meningkatkan mendukung kemampuan literasi statistik mahasiswa dengan implementasi TPACK. Empat belas mahasiswa yang mengambil mata kuliah Statistika Dasar berpartisipasi sebagai subjek dalam penelitian ini. Tahapan pada penelitian ini yakni : *preliminary design*, *teaching experiment*, dan *retrospective analysis* untuk mengembangkan *learning trajectory* melalui aktivitas-aktivitas belajar yang telah didesain melalui *Hypothetical Learning Trajectory* (HLT). Data dikumpulkan dengan menggunakan observasi, wawancara, rekaman video, tugas proyek statistik, dan test. Data dianalisis dan diambil kesimpulan. Hasil dari penelitian ini adalah serangkaian aktivitas belajar yang terintegrasi dengan TPACK dapat digunakan untuk mendukung kemampuan literasi statistik mahasiswa calon guru meliputi aktivitas : *data awareness, statistical conceptual and idea, data presentation, dan data representation*. *Local Instructional Theory* (LIT) yang dihasilkan bermanfaat dalam pembelajaran statistika dasar untuk mendukung kemampuan literasi statistik mahasiswa calon guru matematika.

Kata kunci: *design research*, kemampuan literasi statistik, TPACK, *validation study*

Abstract

The development of ICT in the industrial revolution 4.0 was very fast and unlimited, causing the importance of statistical literacy for mathematics students' teachers as global citizens, and future mathematics teacher candidates to be able to interpret and criticize information before communicating it in various media. This study described Technological Pedagogical Content Knowledge (TPACK) in supporting the statistical literacy skills of mathematics students' teachers. The method used in this research was a design research type validation study to support students' statistical literacy skills by implementing TPACK. Fourteen students who took the Basic Statistics course participated as subjects in this study. Three stages were carried out in this study, namely: the preliminary design, teaching experiment, and retrospective analysis to develop a learning trajectory through learning activities that had been designed through the Hypothetical Learning Trajectory (HLT). Data were collected using observations, interviews, video recordings, statistical project assignments, and tests. Data were analyzed and conclusions were drawn. The results of this study were a series of learning activities that are integrated with TPACK and can be used to support the statistical literacy skills of mathematics students' teachers including activities: data awareness, statistical conceptual and idea, data presentation, and data representation. Local Instructional Theory (LIT) produced was useful in learning basic statistics to support the statistical literacy skills of mathematics students' teachers.

***Keywords**: design research, statistical literacy skills, TPACK, validation study*

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INTRODUCTION

The development of technology, information, and communication that were advancing rapidly in the current digital era was closely related to the ease with which global citizens can access all information widely and unlimitedly (Aziz & Rosli, 2021; Hermawanto & Anggrani, 2020; Khaira et al., 2021; Wahyuddin et al., 2022). Information on an object or person which subsequently became data, which if not processed properly, did not use good analytical methods, will result in an incorrect interpretation of the data (Tiro, 2018). Some studies showed the trend of spreading fake news in society was increasing (Herawati, 2016; Rahmadhany et al., 2021). This was closely related to how people had statistical literacy skills.

The importance of statistical literacy skills, namely the ability to access, analyze, interpret and communicate data critically and accurately for students who were also part of global citizens was mandatory in the national curriculum (Gal, 2004, 2019; Kemendikbud, 2017, 2020). Good statistical literacy skills affected the use of statistics and their relevance to the development of social, and economic nationalism, and other sections (Aziz & Rosli, 2021; Fernández et al., 2020; Gal, 2004; Rumsey, 2002; Tiro, 2018). More Specifically in the education field, the literacy statistics skills for practitioner education could be used to change learning strategies to become better students' statistical literacy and probabilistic skills citizens (Muñiz-Rodríguez et al., 2020).

Statistical literacy skills were given to students from elementary school to higher education, contained in subjects mathematics subchapter statistics and statistics courses (Astuti & Prabowo, 2020; Khaerunnisa & Pamungkas, 2017). The statistical literacy skills of students in Indonesia were still not optimal (Idris, 2019; Tiro, 2018). Optimizing students' statistical literacy skills within the scope of higher education can be done and given to mathematics students who took basic statistics courses by providing an understanding of the basic competencies of statistics. Rumsey (2002) and Gal (2004, 2019) state that basic statistical competencies include data *awareness*, understanding of basic statistical concepts, basic data collection, basic interpretation skills, and communication skills (Gal, 2004, 2019; Rumsey, 2002).

Technological Pedagogical Content Knowledge (TPACK) was a framework for integrating technology into the learning process that involved packages of technology knowledge, pedagogy cover learning processes or strategies, materials, and content knowledge (Heru et al., 2021; Oster & Peled, 2014; Rafi & Sabrina, 2019; Wijaya, Purnama, et al., 2020; Wijaya, Tang, et al., 2020). A learning process that did not only involve pedagogy, and content knowledge but the use of technology was very important in the learning process, it provided learning experiences as well as soft skills for students to answer challenges in the era of the industrial revolution 4.0 and society 5.0 which was closely related to data to support the student's literacy skills (Aziz & Rosli, 2021; Dini et al., 2020; Kemendikbud, 2020; Oster & Peled, 2014). So that they could be critical in taking conclusions to something existing phenomena/ events in society, no occur the spread of hoaxes (Gal, 2019; Rahmadhany et al., 2021; Tiro, 2018).

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Seeing the importance of statistical literacy skills that mathematics students' teachers as also global citizens, making this research urgent to be carried out. This study aimed to describe how can TPACK as a learning framework included technology, pedagogy, and content knowledge can support the statistical literacy skills of mathematics students' teachers.

METHOD

This study was a descriptive study for describing TPACK implementation to support the statistical literacy skills of mathematics students' teachers. The method used was a design research type validation study for developing the Hypothetical Learning Trajectory (HLT) which consisted of learning activities integrated with TPACK. Some stages taken in a study were the preliminary design stage, the teaching experiment stage, and the retrospective analysis stage (Bakker, 2018; Gravemeijer & Cobb, 2006; Prahmana, 2017).

In teaching, the experiment stage shared became two stages that were the pilot experiment stage (cycle 1) and the teaching experiment stage (cycle 2). Figure 1.a. and Figure 1. b. following explained the cyclic processes that exist in design research and the stages carried out in this research.

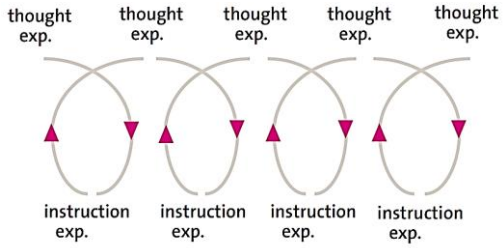

Figure 1.a. Cyclic process in design research (Gravemeijer & Cobb, 2006)

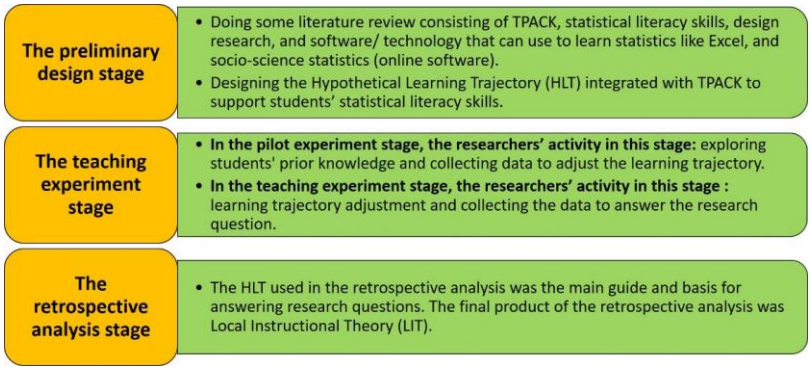

Figure 1.b. the flowchart of the research

The total number of students who participated in the research was 14 students from the mathematics education study program of faculty teacher training and education of Sjakhyakirti University who took a basic statistics course. In the pilot experiment stage (cycle 1) four students of C class participated in this stage, and at the teaching experiment stage (cycle 2) as many as ten students from A class participated in this stage. Data were collected through observation, interview, video recording, and project assignment. Data were obtained by retrospective analysis of the develop-

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ment of the HLT. Data analysis was carried out by researchers and in collaboration with the course, lecturers to increase the validity and reliability of this study. Data analysis of interviews, observations, video recordings, and project assignments qualitatively and quantitatively.

RESULT AND DISCUSSION

The preliminary design stage

The researchers collaborate with lecturers in basic statistics courses to design plans/ alleged learning trajectories or design the TPACK-integrated Hypothetical Learning Trajectory (HLT) to support students' statistical literacy skills. Before designing the HLT at the preliminary stage, the first thing to do was literature reviewed about previous research related to statistical literacy, TPACK, and content in the basic statistics course at the mathematics education study program, FKIP Sjakhyakirti University. At this stage, HLT was produced in the form of a learning trajectory in basic statistics courses as shown in Figure 2. Learning trajectory for supporting students' statistical literacy skills.

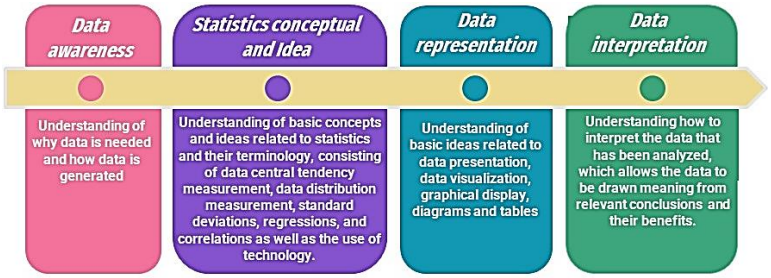

Figure 2. Learning trajectory for supporting students' statistical literacy skills

The learning trajectory in Figure 2 was compiled based on theories of learning statistics, statistical literacy, and curriculum in the mathematics education study program. After the learning trajectory was designed then a series of TPACK-integrated learning activities were also designed at this stage, Figure 3 was the learning activities integrated with TPACK support students' statistical literacy skills was a TPACK-integrated learning activity that has been designed in collaboration with lecturers.

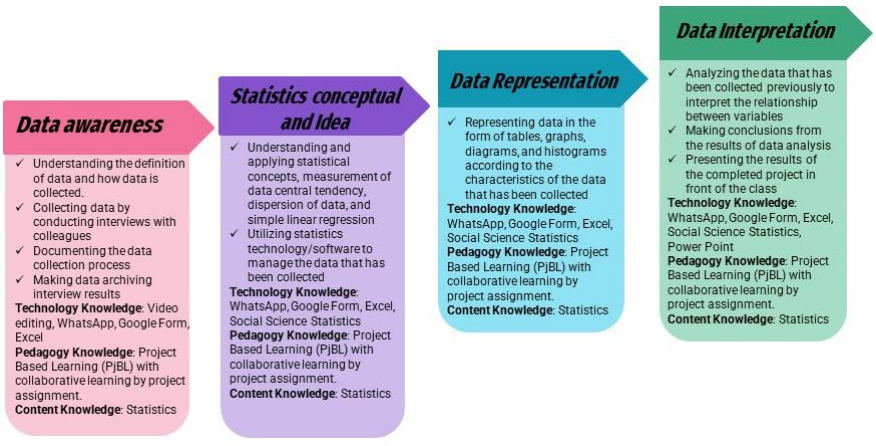

Figure 3. The learning activities integrated with TPACK support students' statistical literacy skills

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The learning activities integrated TPACK in Figure 3 showed that for pedagogy using project based learning, and some of technology, such as: Excel, video editing, WhatsApp, and Google Form. The learning activities integrated with TPACK in Figure 3 then piloted with four students namely the teaching experiment-pilot experiment stage in cycle 1.

The teaching experiment – pilot experiment stage in cycle 1

At this stage, the cycle 1 pilot experiment was tested on 4 students in 2nd semester of class C who took basic statistics courses, they were working in one group. The results of the initial pretest of students showed that students were not familiar with the application of socio-science statistics and even Excel. Some of the students had never operated or experienced them. These facts, of course, affect the implementation of learning activities that have been designed, so technological knowledge at this stage only focuses on Excel.

In completing the project assignments given, students also need to be motivated to complete the data collection process in groups (data awareness activities), because based on the results of monitoring with students, only a few participated in the data collection process, while others did not contribute. Whereas by participating in this learning activity, students' statistical literacy skills were emerging by knowing how the sampling process (data collection), how primary data was collected from data sources, and the sustainability of this activity was to be able to build other statistical literacy skills such as data processing using concepts and concepts. statistical ideas, presenting data and interpreting data. So to anticipate this situation, students must be provided motivation and monitored so that they can work together in completing the project by the end.

The results of the pilot experiment showed that the TPACK integrated basic statistics learning design to support students' statistical literacy skills has an important role wherein every learning activity that has been designed to provide statistical knowledge to students, even though in some learning activities the results are not optimal. During the learning process using a project-based learning model by utilizing technology such as WhatsApp, Google Forms, Excel, and PowerPoint, able to facilitate students to complete a given project, such as collecting data, managing data, representing data, and interpreting existing data so that students can conclude dealing with existing statistical problems.

The retrospective analysis of the pilot experiment stage

HLT development was focused on using Excel technology as a data processing application/software, for the second cycle teaching trial stage, there was one additional meeting that was used to learn Excel before project assignments because there were students who have never studied Excel in high school, for students who have already studied can reinforce how to operate Excel. Figure 4 is the result of HLT development based on cycle one.

Figure 4 development of HLT in a series of learning activities was the development of the learning trajectory that underwent revisions or changes based on the results of the retrospective analysis in cycle 1. The results of the HLT development were tested in cycle two.

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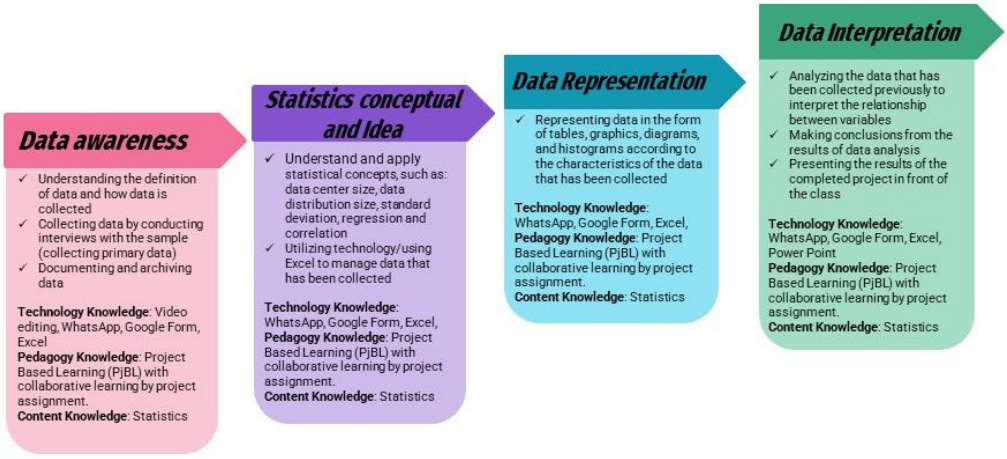

Figure 4. Development of HLT in a series of learning activities

The teaching experiment – teaching experiment stage in cycle 2

The teaching experiment stage was the core stage of design research because at this stage the HLT that has been designed and improved in the previous stage was tested in the real class that was the subject of the research. The results of the research at this stage were to answer research questions. Lecturers who teach courses act as teachers while did some observed for each student's learning activities. Before the learning activities (teaching experiment) were carried out, the lecturers and researchers discussed the learning activities on that day. During the learning process, ideas and assumptions can be modified as a revision of the Local Instructional Theory (LIT) for the next activity. Furthermore, after the learning activities were completed, researchers and lecturers reflect on the learning activities that have been carried out to improve the next learning.

In implementing the teaching experiment, data collected by documenting student learning activities through video recordings and photos, as well as collecting student work and selecting several students to be interviewed. At this stage, the research was carried out in class A with the number of research subjects being 10 students who took basic statistics courses. They work in groups of 3 to complete a given statistical project. This study was conducted five times with a series of learning activities, namely data awareness (DA), statistics conceptual and idea (SI), data representation (DR), and data interpretation (DI) which have been developed from HLT in (Fig.4).

The following are the results of student project assignments for each learning activity from cycle 2, which can be seen in Figure 5. The results of the student statistics project evaluation.

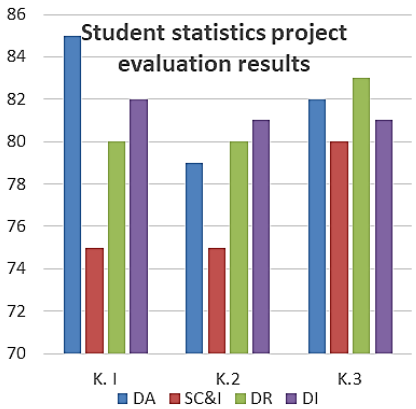

Figure 5. Student statistics project evaluation results

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Description of Figure 5. Students statistics project evaluation results
DA : Data Awareness
SC & I : Statistics Conceptual & Idea
DR : Data Representation
DI : Data Interpretation
K.I : Group 1
K.2 : Group 2
K.3 : Group 3

Based on Figure 5, it can be seen that group 3 has the most optimal results because for the four learning activities the group can balance project assignments from learning activities of data awareness, statistics conceptual and idea, data representation, and data interpretation. The overall project assignment results for group 1 got an average score of 80.5 in the very good category, group 2 got an average score of 78.75 in the good category, and group 3 got an average score of 81.5 in the very good category. Overall, the results of project assignments with learning activities designed and implemented by students got an average of 80.25 (with a very good category). (Referring to the academic guidelines of Sjakhyakirti University, category A gets a score of 80.00 – 100 B with a score of 70.00 – 79.99).

The retrospective analysis of the teaching experiment stage

The data obtained from the cycle 2 teaching experiment stage was re-analyzed at this stage, then the analysis was used to develop Local Instructional Theory. The results of the second cycle retrospective analysis are as follows:

1. Activity Data Awareness

In this learning activity, students can collect data by conducting interviews with respondents with a sample of 60 students from different faculties, and semesters. Students can explain and provide reasons for the sampling process they use, although in some cases the sampling process does not fully represent the characteristics of the desired sample, this provides a learning experience for students in determining the sample whose data they take. This experience is certainly useful for them later in the process of completing the final task (thesis).

The use of video editing applications to edit the data collection process shows that students can take advantage of technology in learning, although in using Excel there are still students who have not studied. Students who take this course are students who during high school experienced an online learning phase for 2 years (4 semesters) due to the covid-19 pandemic, this may be the reason why there are students who have never studied Excel in high school before. Because students experience the learning phase from home, the use of Excel that should be done at school is not implemented. In this data collection activity, there is also a collaborative process in the completion of the projects they are working on, students are motivated to contribute to completing the project because the given project is closely related to other projects.

For optimizing the use of Excel, this lesson should be given outside class hours, 2-3 times a meeting. To learn about formulas and data analysis in Excel. Furthermore, in learning basic statistics, students only need to apply statistical concepts and ideas in solving problems and answering questions on how to interpret the data that has been processed and analyzed.

2. Activity Statistics Conceptual and Idea

At this stage, students can apply basic statistical concepts to find

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measures of data concentration, size of data distribution, and standard deviation, but students have not been able to use tools in data analysis to find regression and correlation of relationships of two or more variables. Students still use manual methods to find simple regression coefficients even though they use excel for computation. This is good when you use Excel for computing but it is not optimal in using other features, such as data analysis.

3. Data Representation Activities

At this stage by using Microsoft Excel students can represent data in various forms representation such as diagrams, and tables, using the chart feature in Excel. Students can also choose the right data representation to use for the data that has been collected, namely the use of tables, and scatters and they can give the right reasons why they choose that representation.

4. Data Interpretation Activities

Students can interpret data to conclude a given problem. In this activity, students also present the results of projects that have been carried out from the stages of data collection, data processing, data presentation, and conclusion drawing. The technology they use is also good using Excel and PowerPoint to present the results of project work in groups.

Discussion

Technological Pedagogical Content Knowledge (TPACK) in this study included Technological Knowledge, Pedagogical Knowledge, and Content Knowledge. Technological Knowledge was using Excel to process data, present data and with Excel can interpret data. many technologies can be used for statistical applications, but Excel was indeed an easy application to use in managing and presenting data. This was following a study that states that Excel can increase students' activeness and learning outcomes in statistics (Indriati, 2022) although currently many technologies were more complicated and complex in learning, such as SPSS, Python, and others, they adapt to students' abilities. students as well as the facilities and infrastructure available from the campus.

The pedagogical Knowledge used in this research was project-based learning. Project-based learning with learning activities that have been designed to include: data awareness, statistical conceptual and idea, data representation, and data interpretation can support students' statistical literacy skills. Studies showed that project-based learning can develop students' abilities and skills in the 21st century (Ravitz et al., 2012; Rusmining, 2022; Utari, 2018; Wicaksono et al., 2015). One of these abilities was literacy skills, especially statistical literacy.

The content knowledge in this study was basic statistics that follows the syllabus of the basic statistics course in the mathematics education study program, at FKIP Sjakhyakirti University. In addition, various references were used to organize learning activities to support statistical literacy skills, namely: data awareness, statistical conceptual and idea, data representation, and data interpretation. The learning trajectory described in this learning activity was by the research by

(Rumsey, 2002) and (Gal, 2004, 2019) on statistical literacy which then with design research through a cyclical process (teaching experiment) and retrospective analysis can increase the relevance of research. This is also in line with studies on design research that can improve the quality of learning and

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increase the relevance of research (Bakker, 2018; Gravemeijer & Cobb, 2006; Prahmana, 2017; Reeves, 2006). Further research, further research can be carried out with a larger number of research subjects who are representative of each university level. The use of various technologies can also be used for further research, perhaps on the condition that at least the students already have learning experience or already know beforehand the technology, so that when conducting research is more effective.

The findings in this study were that the implementation of the TPACK framework can support the statistical literacy abilities of students' teacher, the use of design research for interventions in learning in compiling learning trajectories consisting of learning activities. This was consistent with previous research which states that the implementation of the TPACK framework can improve student learning outcomes (Khaira et al., 2021).

The activities that have been designed support students' statistical literacy skills where students were required to think critically in solving the given of problems and projects statistics. Statistical literacy was an important thing for prospective mathematics students' teacher, where in the future they will teach this to the next generation. The good statistical literacy skills, can arrange what strategies can be used in learning. This hope is in accordance with research that good statistical literacy can influence various decisions that support the development of a nation in the future (Muñiz-Rodríguez et al., 2020; Tiro, 2018).

The contribution of this research, implementation of TPACK in basic statistics courses was Local Instructional Theory (LIT). Local Instructional Theory which consists of learning activities, including: data awareness, statistical conceptual and ideas, data representation, and data interpretation which can support the statistical literacy skills of mathematics students' teacher.

CONCLUSIONS AND RECOMMENDATIONS

Technological Pedagogical Content Knowledge (TPACK) was a framework that can be used to support students' statistical literacy skills. The implementation of TPACK included technology, project-based learning implementation, and basic statistical content in learning designed for a series of learning activities, including activities: data awareness, statistical conceptual and idea, data presentation, and data representation that can be implemented to support students' statistical literacy skills.

A series of learning activities, and the use of technology that was designed in such a way, illustrate that statistics and data exist in all aspects of life. With statistical literacy, students can expect possibilities that will occur in the future, with the use of technology in learning students have been equipped with soft skills for the use of technology such as Excel, and PowerPoint which can develop ideas and statistical concepts from the problems given. So it can be said that the TPACK integrated basic statistics learning design can support students' statistical literacy skills in the era of the industrial revolution 4.0.

Further research can be carried out to develop students' statistical literacy skills with a wider range of research subjects, more varied statistical projects, and the use of more qualified technology or software or application that can support students' statistical

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literacy skills and may be able to use applications available free of charge on the internet, which are currently thriving in society.

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