Technological pedagogical and content knowledge (TPACK)
of science teachers in a suburban area

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Abstract. The aim of this study is to examine junior high school science teachers’ TPACK levels in District Aceh Besar and to find out the differences between teachers’ TPACK according to their educational background, years of teaching experience, and certification. The TPACK data were collected using a survey method with validated questionnaires. The respondents were 71 science teachers from 33 junior high schools representing all science teachers in District Aceh Besar, a suburb of Banda Aceh city. The data were analyzed using descriptive statistical analysis, specially ANOVA and an independent t-test. The research findings indicate that teachers are more knowledgeable about pedagogical and content domains than in technological. Progress of teachers’ TPACK mean score followed the educational degree level but the teaching experience and professional certification did not have a significant effect on TPACK improvement. Based on this study, science teachers in Aceh Besar need to improve their knowledge and skills in technology and TPACK to face the education challenges present in the Industry 4.0 era.

1. Introduction
The education system in the era of Industry 4.0 is expected to stimulate students to be creative, innovative, and independent in their studies by using information and communication technologies (ICT) [1]. The Indonesian Ministry of National Education (MoNE) has mentioned that teachers need to integrate ICT in the learning and teaching process [2]. To support ICT integration in the learning and teaching process, MoNE has made an effort to provide ICT infrastructure in schools such as computers and internet connection [3]. Therefore, teachers must have sufficient knowledge about using ICT as part of teaching media and learning sources.

Teachers are expected to have the capacity to choose the appropriate technology that is suitable to the subject matter. The teaching strategy should also be compatible with technology in order to integrate technology, pedagogy, and content knowledge. The interaction between these three basic kinds of knowledge known as TPACK and several other combinations are also used such as pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), and technological content knowledge (TCK) [4,5,6]. TPACK is a combination of the knowledge and skills...
needed to integrate technology in teaching in order to facilitate effective student learning [7]. This framework is based on Pedagogical Content Knowledge (PCK), an existing construct that was first introduced by Shulman (1986), with the addition of technological knowledge. It requires an understanding of how technology can be used to represent concepts, pedagogical techniques that use technology in new ways to teach concepts, and knowledge of what makes a concept difficult or easy to learn and how technology can help to fix it [8]. TPACK is currently considered an important quality for qualified teachers [9]. It also potentially emphasizes teacher’s understanding of how technology can be used effectively as a pedagogical tool [10].

The TPACK framework can also be used to identify teachers’ perceptions about the various dimensions of knowledge and assess teachers’ professional development needs [11]. There have been a number of studies that have developed instruments to measure teachers’ TPACK because many types of research point out the importance of teachers’ TPACK assessments [12]. The most commonly used method to investigate teachers’ knowledge and levels of TPACK is self-reporting and assessment surveys. TPACK surveys including the seven domains of TPACK as TK, CK, PK, TPK, TCK, PCK, and TPACK were developed by previous studies [13,14]. However, international literature about TPACK generally focuses on the issues of pre-service teachers’ TPACK [15,16][17]. Few published studies have investigated in-service teachers’ TPACK through surveys with respect to teachers’ demographic profiles. Even though it has been suggested in the literature that the relationship between the TPACK constructs and teachers’ demographic variables need to be identified further [18,19,20,21]. Since the TPACK level of science teachers in suburban areas with respect to their demographic profiles have not been studied yet, this study attempts to bridge this gap. Thus, the main purpose of this study is to examine junior high school science teachers’ TPACK levels in District Aceh Besar and find out the differences between teachers’ TPACK according to their educational background, years of teaching experience, and certification.

2. Method
This is a descriptive research study using a survey method. The population in this study is junior high school science teachers (226 persons) in Aceh Besar. The sample was selected using a purposive sampling technique and included 71 teachers from 33 junior high schools in Aceh Besar. They were all civil servants and were born at the latest in 1968 when they were beginning to use the computer in their careers.

Data was collected by distributing validated questionnaires. The TPACK questionnaire consisted of questions on the teacher’s demographic information, the IT facilities at their schools, and a questionnaire on TPACK with 5-point Likert scales that were verified and adjusted based on previous studies [13][22]. The TPACK questionnaire in this study was also divided into seven domains; TK, PK, CK, TPK, TCK, PCK, and TPACK. Before the survey was used, it was reviewed and validated by five experts. The mean validated score was 97.1% which implied that the instrument was valid and feasible to use for measurement of TPACK. The survey was further used in a trial for ten junior high school teachers to obtain their responses in case there were any ambiguous questions in the survey. The majority (89.3%) of questions were considered worthy and 10.7% needed minor corrections and were revised accordingly. Descriptive analysis was used to describe the science teachers’ TPACK capacity, and comparative ANOVA and independent t-test techniques were used to examine the statical difference in science teachers’ TPACK according to their demographic profiles such as educational background, years of teaching experience, and certification.

3. Results and Discussion
The demographic profiles of teachers who responded to the survey in this study are presented in Table 1 below. Table 1 shows that a majority of respondents (93%) were women and categorized as middle-age (43.7%) and older-age (50.7%) adults. Therefore, the majority of participants were considered in the early elderly category, 94.5% of teachers have bachelor's degrees and most of them graduated from a teacher training institution. 80.3% have teaching certificates as professional teachers. Out of 33
schools, only 79% have IT supporting facilities such as computer laboratories, network connection, and LCD projectors. In many cases, the supporting facilities were under the control of IT teachers and not all teachers had permission to use them for their teaching classes. This is one of the obstacles for science teachers in integrating digital technology into teaching and learning activities.

Table 1. Characteristics of junior high school science teachers’ in Aceh Besar

| Characteristic               | Categories          | Frequencies | (%)  |
|-----------------------------|---------------------|-------------|------|
| Gender                      | Male                | 5           | 7    |
|                             | Female              | 66          | 93   |
| Age                         | 25 – 35 years old   | 4           | 5.6  |
|                             | 36 – 45 years old   | 31          | 43.7 |
|                             | 46 years old or older| 36          | 50.7 |
| Teaching experience         | 1 – 5 years         | 2           | 2.82 |
|                             | 6 – 10 years        | 16          | 22.53|
|                             | 11 – 15 years       | 25          | 35.21|
|                             | 16 years or more    | 28          | 39.44|
| Educational Level           | D3                  | 2           | 2.8  |
|                             | S1                  | 67          | 94.4 |
|                             | S2                  | 2           | 2.8  |
| Certification Status        | Non-Certified       | 14          | 19.7 |
|                             | Certified           | 57          | 80.3 |
| Have a personal computer    | Yes                 | 63          | 88.7 |
|                             | No                  | 8           | 11.3 |

The normality test used in this study was the Kolmogorov-Smirnov technique using the SPSS program. Based on the normality test that was done, it was found that the normal distribution of TPACK scores in this study was K-S-Z=0.093 with p=0.200 or p>0.05. This shows that the data obtained in this study has a normal distribution. The results of the homogeneity test were 0.064. In other words, the significant value obtained was more than 0.05 (p>0.05) and it can be concluded that the data in this study had the same variants. Besides teachers’ demographic profiles, TPACK data were collected using a validated questionnaires and the domain displayed in Table 2.

Table 2. Descriptive statistics of science teachers’ TPACK in each domain.

| TPACK Domains | N  | Mean | Standard Deviation | Category   |
|---------------|----|------|--------------------|------------|
| TK            | 71 | 2.13 | 0.78               | Low        |
| CK            | 71 | 3.32 | 0.80               | Medium     |
| PK            | 71 | 3.94 | 0.79               | High       |
| TPK           | 71 | 3.37 | 1.01               | Medium     |
| TCK           | 71 | 3.01 | 0.76               | Medium     |
| PCK           | 71 | 3.63 | 0.57               | High       |
| TPACK         | 71 | 2.42 | 0.76               | Low        |

Table 2 shows that Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK) among teachers are considered high. This indicated that nearly all of teachers have the capacity to teach conventionally. However, they are still weak in science content and have a low capacity for using technology in teaching and technology for content resources as reflected by their medium capacity in Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK). Science teachers’ knowledge of technology terminology such as terminology used in internet browsing is considered low. Finally, the overall TPACK is also insufficient. These findings follow the previously reported studies that show that teachers have more knowledge in the pedagogic and content fields than in technology [23]. This implies that the current level of teachers’ technological knowledge causes teachers to have a low capacity to integrate technology into their classrooms. Although 88.7% of teachers have their own computer that is used at
home or in the classroom, this does not have a significant effect on teachers’ TPACK. This confirms previous studies that report that teachers who use technology for communication and information daily can not necessarily integrate technology in their classroom if they have no capacity to interpret the technical knowledge in their teaching [24].

3.1. Educational Background and Teachers’ TPACK

An ANOVA analysis of science teachers’ TPACK according to their educational background can be seen in Table 3.

**Table 3.** ANOVA analysis of science teachers’ TPACK according to teachers’ educational background.

| Teachers’ Educational Background | Mean | Percentage | ANOVA F(df) | Sig. |
|----------------------------------|------|------------|-------------|------|
| D3                               | 64.00| 45.71%     | 6.388       | 0.003|
| S1                               | 87.60| 62.57%     |             |      |
| S2                               | 104.50| 74.64%     |             |      |

As we can see in Table 3, there is a significant difference in teachers’ TPACK based on their educational background. The TPACK increased with a higher level of education. The higher education level may cause teachers to have more experiences and opportunities related to using technology. This experience may improve their capacity and confidence in using various kinds of technology in daily life and in teaching and learning activities [25]. When teachers face more challenges and demand to develop their skills, they will develop better knowledge and skill in technology, pedagogy, and content so that it becomes easier to integrate TPACK into the learning process [26].

3.2. Length of Teaching Experience and Teachers’ TPACK

Although the TPACK differences are not significant at p = 0.05 (Table 4), the young teachers (1-16 year teaching experience) have a slightly higher TPACK than the elder generation (>16 year experience). Unlike the elder generation, the young teachers have more experience using ICT in their learning process during their enrolment in University.

**Table 4.** ANOVA analysis of science teachers’ TPACK according to teachers’ length of teaching experience.

| Years of teaching experience | Mean | Percentage | ANOVA F(df) | Sig. |
|------------------------------|------|------------|-------------|------|
| 1 – 5 years                  | 90.50| 64.64%     | 0.886       | 0.453|
| 6 – 10 years                 | 83.00| 59.28%     |             |      |
| 11 – 15 years                | 89.57| 63.97%     |             |      |
| ≥ 16 years                   | 87.07| 62.19%     |             |      |

This finding was consistent with previous studies that showed that the length of teaching experience had no significant impact on technological, pedagogical, and content knowledge [27]. Teachers with less teaching experience tend to be younger and grew up with technology. They were more open to accepting technology in learning and tend to use technology for educational purposes [28,29]. The elder generation with higher teaching experience has better knowledge in pedagogical and content domains. These results were in line with previous studies [30,31,32] which state that teachers who had more than 15 years of teaching experience (experienced teachers) usually had lower self-confidence in integrating technology in the classroom compared to less experienced teachers. However, due to more years of teaching experience, experienced teachers had higher pedagogical and content knowledge than teachers who had less teaching experience.
3.3. Certification and Teachers’ TPACK
Professional certification of teachers has no significant contribution to TPACK enhancement as displayed in Table 5. There are no significant TPACK differences between certified and non-certified teachers’ TPACK.

| Teachers’ Certification Status | Mean | Percentages | t-test | Sig. |
|-------------------------------|------|-------------|--------|------|
| Non-certified                 | 82.29| 58.77%      | 1.761(69)| 0.083 (p>0.05) |
| Certified                     | 88.67| 63.33%      |        |      |

However, the enhancement of TPACK scores of certified teachers might be caused by other factors such as the state of school, supervision of the principal and teachers’ quality after certification. Supervision of the principal has a positive and significant influence on teachers’ TPACK ability. A visionary school principal will always strive to organize activities that can enhance teachers’ insight and knowledge including the use of the latest teaching technology [33].

4. Conclusions
Generally, science teachers in Aceh Besar junior high schools have a lack of knowledge in technology but have more pedagogical and content knowledge. TPACK training is needed to improve teachers’ knowledge and skills in integrating educational technologies to face the education challenges in the Industry 4.0 era. Schools are recommended to hire young and highly qualified teachers. Due to the limitations of this study, we suggest conducting future research to compose an effective TPACK training pack.

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