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Analysis of Mathematics Teaching Devices of Teachers Based on the Integration of TPACK (Technological, Pedagogic and Content Knowledge)

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Abstract. This study aims to describe the results of analysing the learning device model of teachers who have optimally integrated TPACK in public middle school teachers in West Lombok Regency. This research uses a qualitative descriptive method with a quantitative approach. A qualitative descriptive method was used during the development of the device until its validation, while a quantitative approach was employed during the limited trial. The population in this study consists of teachers at public middle schools with the status of driving schools in West Lombok Regency, involving a sample of 6 schools with the status of driving schools. The results showed that the mathematics teaching devices implemented by teachers have generally integrated TPACK. This is indicated by an average score of 3.94 in the medium category.

Keywords: Teachers; Teaching Device; TPACK Integration.

INTRODUCTION

Technological advancements have a significant impact on education; this is due to technology-enhanced education's effectiveness, efficiency, and appeal. The increasingly sophisticated advancement of information technology necessitates that teachers master technology to be used as a medium for teaching and learning activities in the classroom. Quality education can significantly support achieving better human development goals in Indonesia. The education sector must keep pace with and exceed the developments in science and technology, particularly in the learning process.

Teachers must possess competencies to conduct the learning process effectively. According to authors [1], there are four competency standards that teachers in Indonesia must possess: pedagogical competence, social competence, personal competence, and professional competence. Pedagogical competence is one of the competencies that determine the success of a learning process. According to authors [2], the concept of pedagogical competence tends to be used as a standard for minimum professional requirements, often considered as a law, which will enhance and complete the role of the teaching profession. Indonesian Government Regulation No 19 of 2005 states that pedagogical competence is the teacher's ability to manage learning, which includes understanding students, planning, implementing learning, evaluating learning outcomes, and actualising all student potentials. Pedagogical competence is the teacher's ability to organise and manage learning from planning, implementation, assessment of the process, and learning outcomes.

Next, the competence that teachers must possess is professional competence. Professional competence is mastering the subject matter authors [1]. Rapid technological developments require teachers to improve their professional competence. Besides being able to teach in the classroom, teachers must also be able to integrate technology into learning.

Indonesia's new Minister of Education and Culture, Nadiem Makarim, has caused pros and cons from various circles since issuing Circular No 1 of 2020 on the policy of independent learning in determining student graduation. "Merdeka Belajar" or "Freedom to Learn" involves freeing educational institutions and encouraging students to innovate and foster creative thinking. Considering the vision and mission of Indonesia's education for the future, which aims to create quality individuals capable of competing in various fields

of life, educators have accepted this concept. In the era of the 4.0 revolution, we expect the education system to produce students with critical thinking skills, problem-solving abilities, creativity, innovation, and communication and collaboration skills [3].

With the development of educational policies, teachers must be able to adapt to the prevailing policies. Teachers play a crucial role in the learning process. As professionals, teachers must deliver high-quality education that produces well-educated generations, competes globally, and possesses good morals authors [4]. The learning process will be engaging and enjoyable if teachers can creatively design their lessons. Teachers can choose suitable methods and use teaching media to help students understand the material. Learning will not become monotonous using varied teaching methods and appropriate teaching media. Thus, the government will effectively achieve its goals and policies on independent learning. However, many teachers still feel confused and are not accustomed to using teaching media. Teachers' methods in the learning process often include only lectures or assignments.

To realise the independent learning program, the government has initiated the teacher program to motivate teachers to fulfil their roles in independent learning. Indonesia is one of the countries that implements the education pattern with teachers in independent learning. A teacher in independent learning can guide students to develop holistically, foster critical thinking, and nurture creative innovation. Nadiem Makarim, the Minister of Education and Culture of Indonesia, emphasised that the teacher spearheaded the transformation in independent learning. Teachers follow the prescribed curriculum and strive to transform all learning activities to achieve or maintain the standards of the Pancasila Student Profile. This profile includes students who are faithful, devoted, morally sound, creative, collaborative, globally diverse, critical thinkers, and independent.

Teachers must balance the demands of the modern era with character education as the foundation for students to wisely face the challenges of an evolving era and critically respond to all available information. As a government policy program, teachers must be able to integrate technology by possessing knowledge about technology, pedagogy, and content. The ability of teachers to incorporate technology into the learning process can be seen through their Technological, Pedagogical, and Content Knowledge (TPACK). This ability is essential for teachers, especially for teachers. According to authors [5], TPACK is the relationship between three primary sources: content knowledge, pedagogical knowledge, and technological knowledge. The aspects of technological, pedagogical, and content knowledge, according to authors [5, 6], include seven areas: Technology Knowledge (TK), Content Knowledge (CK), Pedagogical Knowledge (PK), Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Technological, Pedagogical, and Content Knowledge (TPACK). Teachers can use TPACK to appropriately integrate technology into learning based on material characteristics and pedagogical aspects [7]. Therefore, teachers must be optimally equipped with TPACK skills to incorporate technology into learning, creating effective and engaging education.

According to authors [9], we can see teachers' TPACK abilities from their lesson plans, which include pedagogical components (methods used), content components (material taught), and technology components (media used). Hence, learning tools should incorporate TPACK components, as these tools reflect the teachers' teaching methods.

However, the TPACK abilities of teachers still need improvement. Some teachers have not optimally integrated TPACK into their teaching media despite the rapid development of information and communication technology. According to [10], the impact of technological developments demands that teachers innovate and creatively use technology as a teaching medium. Using teaching media can undoubtedly help teachers deliver the material. Therefore, teachers must prepare themselves to become professional educators who can manage the learning process, master the subject matter, and effectively use technology.

METHOD

The method used in this research is the descriptive qualitative method, which functions to describe or illustrate the research object through sample or population data as it is. This method emphasises detailed, complete, in-depth sentence descriptions depicting the actual situation

to support data presentation [11]. In this case, the researcher uses the descriptive method to analyse the results of teachers' technological, pedagogical, and content knowledge (TPACK) capabilities implemented in public middle schools with status in West Lombok Regency. The subjects of this research are teachers in West Lombok Regency. The sampling technique used is purposive sampling, which involves selecting data sources with specific considerations, such as individuals who are deemed to know the most about what the researcher is investigating [12]. The research sample includes 15 teachers from 6 schools. Data collection techniques in this study used a questionnaire with an instrument in the form of a survey containing statements about Technological, Pedagogical, and Content Knowledge (TPACK).

Qualitative data is processed using descriptive statistics within the scope of categorisation with a Likert scale. The procedure for data analysis is derived from research instruments using a Likert scale, as shown in Table 1.

Table 1 – Likert Scale Categories [12]

Category	Average value	Percentage
High	4,00–5,00	≥80%
Medium	3,00–3,99	60%–79%
Low	1,00–2,99	<60%

The formula used to convert the scores obtained into percentages is as follows.

$$Value = \frac{\text{Selected Score}}{\text{Maximum Score}} \times 100 \qquad (1)$$

The conceptual framework of this research is to assess the ability of teachers to apply learning tools based on Technological, Pedagogical, and Content Knowledge (TPACK). This research data presents the components of TPACK, which include Content Knowledge (CK), Pedagogical Knowledge (PK), Technological Knowledge (TK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK). Authors [14, 15] explain that Technological Pedagogical Content Knowledge (TPACK) has three main components: technological, content, and pedagogical knowledge. Among these three components, there are interactions between each pair of components. The diagram illustrating the relationships among the elements of TPACK is shown in Figure 1.

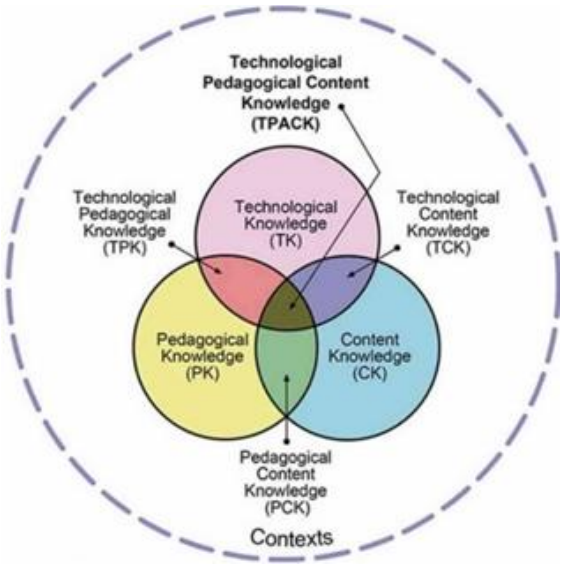

Figure 1 – TPACK diagram [15]

Figure 1 shows that the three main components and the interactions between the two components form a TPACK slice, so seven TPACK components are discussed in the results and discussion section.

RESULTS AND DISCUSSION

Data were obtained from observations of teachers at SMP Negeri 1 Labuapi (3 teachers), SMP Negeri 1 Sekotong (2 teachers), SMP Negeri 3 Sekotong (2 teachers), SMP Negeri 1 Kediri (3 teachers), SMP Negeri 1 Lingsar (3 teachers), and SMP Negeri 1 GunungSari (2 teachers). TPACK analysis is divided into several aspects, namely, Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), Pedagogical Content Knowledge (PCK), and Technological Content Knowledge (TCK).

Descriptive data presented includes mean, mode, median, and standard deviation. The mean is the arithmetic average, the mode is the data value with the highest frequency, and the median is the middle value of a group of data sorted from smallest to most significant data. Standard deviation is a standard measure of deviation from the

average. The results of respondents' questionnaire answers are presented in Table 2.

Table 2 – Calculation Result Data Description of Respondent Questionnaire

Question	Many Respondent	Minimum Value	Maximum Value	Mean	Std. Deviation
1	15	3	5	3,95	0,75
2	15	3	5	4,75	0,55
3	15	2	5	4,05	0,82
4	15	3	5	4,3	0,73
5	15	3	5	4,5	0,60
6	15	3	5	3,7	0,65
7	15	3	5	3,6	0,68
8	15	3	5	3,95	0,76
9	15	3	5	3,95	0,68
10	15	3	5	3,65	0,74
11	15	3	5	4,1	0,78
12	15	2	5	3,8	0,83
13	15	2	5	3,7	0,80
14	15	2	5	3,45	0,75
15	15	2	5	3,75	0,85
16	15	2	5	4,1	0,91
17	15	2	5	3,85	0,87
18	15	1	5	3,45	1,05
19	15	1	5	3,65	0,98
20	15	3	5	3,95	0,75
21	15	2	5	4,1	0,91
22	15	2	5	3,85	0,87
23	15	1	5	3,95	1,05
24	15	2	5	3,8	0,83
25	15	2	5	3,65	0,81
26	15	3	5	4	0,64
27	15	2	5	3,95	0,82
28	15	2	5	4,35	0,87
29	15	3	5	4,2	0,69
30	15	1	5	3,7	0,97
31	15	3	5	4,2	0,69
32	15	3	5	4	0,64
33	15	3	5	3,9	0,71
34	15	3	5	4	0,64
35	15	2	5	3,75	0,91
36	15	2	5	3,8	0,83

*Technological Knowledge***.** Technological knowledge encompasses understanding various technologies, from the most basic to the latest digital technologies. The use of technology must align with the times and continue to evolve. Technological knowledge includes understanding how to use software and hardware in the educational context. It involves adapting and learning the latest technologies, which is necessary due to continuous technological development and changes. Based on data analysis, the survey scores of teachers are presented in Table 3.

Table 3 – Scores of Teachers for Technological Knowledge (TK)

Question Items	Mean	Std. Deviation	Percent age	Criteria
I can utilise appropriate technology in mathematics learning	3,95	0,75	79	Medium
I can connect appropriate technology functions to the learning process.	4,75	0,5	95	High
I can choose the right props for learning mathematics	4,05	0,82	81	High
I can adapt mathematics teaching aids to learning	4,3	0,73	86	High
I can find advantages and disadvantages of software used in learning	4,5	0,60	90	High
I can choose software (media/applications) that suits the learning material	3,7	0,65	74	Medium
Average	4,20	0,68	84,1	High

From Table 3, it is evident that the average score of teachers is at a high criterion in implementing learning tools based on technological knowledge; this indicates that the technological skills of teachers are considered very good; however, it is expected that these skills need to be maintained and further developed. The highest score in technological knowledge was for the item "Can link the functions of technology appropriately with the learning process," with an average of 4.75. Conversely, the item "can select appropriate software (media/applications) for learning materials" received an average score of only 3.70. Overall, they possess adequate technological knowledge with an average score of 4.20 or 84.1% in technology proficiency.

Pedagogical Knowledge. Pedagogical knowledge involves the teaching process, including methods

for classroom management, assessment, lesson planning, and students' learning process [16]. Pedagogical knowledge describes the general objectives of teaching knowledge. Teaching ability is a skill that teachers must develop to manage and organise the classroom effectively and achieve the predetermined goals. Expected knowledge includes understanding classroom management activities, the role of student motivation, lesson planning, and teaching assessments. Pedagogical knowledge also describes knowledge of various teaching methods, including how to organise conducive classroom activities. Based on data analysis, the profile of PK teachers is presented in Table 4.

Table 4 – Scores of Teachers for Pedagogical Knowledge (PK)

Question Items	Mean	Std. Deviation	Percentage	Criteria
I can arrange the assessment form correctly according to the characteristics of the learning material	3,6	0,68	72	Medium
I can manage the class so that students do not get bored in learning	3,95	0,75	79	Medium
I can choose learning strategies according to student needs	3,95	0,68	79	Medium
I can assemble the learning steps to make it easier for students to understand the material.	3,65	0,74	73	Medium
Average	3,79	0,71	75,7	Medium

Based on Table 4, an analysis of pedagogical abilities, the average PK score of teachers is in the medium criteria; this shows that some teachers still have good pedagogical knowledge and cannot fully apply their pedagogical skills in teaching mathematics, with an average score of 3.79 or 75.7%.

Content Knowledge. Content Knowledge is knowledge about the subjects to be studied or taught [16]. Content knowledge refers to knowledge or specificity of a scientific discipline or lesson. This content knowledge differs at each level, from elementary to elementary school. A teacher is expected to master this ability to teach. Content knowledge is also necessary because this ability determines the unique way of thinking about the scientific discipline in each study. We analysed the data to obtain the teacher's CK profile, presented in Table 5.

Table 5 – Driving Teacher Scores for Content Knowledge (CK)

Question Items	Mean	Std. Deviation	Percentage	Criteria
I can solve various kinds of mathematics problems from various mathematics content materials	4,1	0,78	82	High
I can develop various kinds of mathematical solutions from low to high cognitive levels	3,8	0,83	76	Medium
I can make many variations of the correct assessment	3,7	0,80	74	Medium
I can evaluate students' understanding of the content	3,45	0,75	69	Medium
I can prepare project and performance assessment forms to measure student skills	3,75	0,85	75	Medium
I can develop test indicators to measure students' mathematical abilities	4,1	0,91	82	High
I can create mathematical problems related to contextual problems	3,85	0,87	77	Medium
I can create	3,45	1,05	69	Medium

Question Items	Mean	Std. Deviation	Percentage	Criteria
math problems to measure math LOTs, MOTs, and HOTs				
Average	3,77	0,85	75,5	Medium

Based on the results in Table 5, the data analysis of the content knowledgeability of teachers in 6 schools showed an average score of 75.5% in the medium category. This result indicates that the respondent teachers master and teach the material well to the students.

Technological Pedagogical Knowledge. Technological Pedagogical Knowledge (TPK) involves understanding how teachers can use various technologies in teaching and how these technologies can change their teaching methods [16]. TPK occurs due to the reciprocal relationship between technology and pedagogy. This knowledge enables teachers to understand which technologies are appropriate for achieving pedagogical goals and allows them to select suitable media based on feasibility and specific pedagogical approaches.

Technology can provide new methods used in the teaching process and can be easily applied to learning. For example, the online learning system is driven by societal developments and needs, and teachers need to be more innovative and creative. Based on data analysis, the profile of teachers' TPK is presented in Table 6.

Table 6 – Scores of Teachers for Technological Pedagogical Knowledge (TPK)

Question Items	Mean	Std. Deviation	Percentage	Criteria
I can design material stages according to student's level of understanding based on their learning experience.	3,65	0,98	73	Medium
I can choose appropriate learning methods to overcome students' difficulties in understanding the material.	3,95	0,75	79	Medium
I can arrange the stages of the material correctly to support the explanation of the material being taught.	4,1	0,91	82	High
I can design lesson plans using appropriate teaching methods and techniques to develop learning creativity.	3,85	0,87	77	Medium
Average	3,89	0,88	77,8	Medium

From the results of Table 6, data from the analysis of teachers' Technological Pedagogical Knowledge (TPK) abilities in 6 schools showed an average result of 77.8% in the medium category. These results indicate that the respondents can master technological pedagogical knowledge (TPK) well and that it is taught to students well.

Technological Content Knowledge. Authors [16] stated that TCK is an understanding of how technology can create a new image of certain materials. Teachers can take a new approach using TCK on material to teach students. TCK describes knowledge of the reciprocal relationship between technology and content (material). Technology will impact what is known and the introduction of new things, influencing how someone can provide an overview of content (material) differently than before. We obtained the teacher's TCK profile through data analysis and presented it in Table 7.

Table 7 – Teacher Scores for Technological Content Knowledge (TCK)

Question Items	Mean	Std. Deviation	Percentage	Criteria
I can sequence math content combined with technology	3,95	1,05	79	Medium
I can choose the right technology (visual aids/media/software) with math content	3,8	0,83	76	Medium
I can explain mathematical	3,65	0,81	73	Medium

Question Items	Mean	Std. Deviation	Percentage	Criteria
material by utilising technology, including media, teaching aids, and software				
I can prepare material using technology, both visual aids/media and software	4	0,64	80	High
Average	3,85	0,83	77	Medium

From the results of Table 7, the data from the analysis of teachers' Technological Content Knowledge (TCK) abilities in 6 schools showed an average result of 77% in the medium category. These results indicate that respondents can master TCK well in the learning process so that students more easily understand the mathematical concepts presented by the teacher.

Pedagogical Content Knowledge. Pedagogical content knowledge (PCK) is pedagogical knowledge that applies to teaching specific content. This knowledge includes knowing what approaches are appropriate for the teaching process and how content elements can be arranged for good learning [5]. Author [17] stated that effective teaching requires more than separating material and pedagogy. PCK also recognises that different content will suit different teaching methods. PCK means more than just being a content expert or knowing general pedagogical guidelines; it means understanding the specifics of the mutual influence of content and pedagogy. We obtained the teacher's PCK profile through data analysis and presented it in Table 8.

Table 8 – Teacher Scores for Pedagogical Content Knowledge (PCK)

Question Items	Mean	Std. Deviation	Percentage	Criteria
I can design material stages according to student's level of understanding based on their learning experience	3,95	0,82	79	Medium
I can choose appropriate learning methods to overcome students' difficulties in understanding the material	4,35	0,87	87	High
I can arrange the stages of the material correctly to support the explanation of the material being taught	4,2	0,69	84	High
I can design lesson plans using appropriate teaching methods and techniques to develop learning creativity	3,7	0,97	74	Medium
Average	4,05	0,84	81	High

From the results in Table 8, the data analysis of teachers' Pedagogical Content Knowledge (PCK) abilities in 6 schools showed an average score of 81% in the High category. This result indicates that the respondents have good mastery of PCK, and the data shows that respondents can present diverse material.

Technological Pedagogical and Content Knowledge. TPACK is the knowledge of the complex interactions between content, pedagogy, and technology domains. Modern teaching demands that teachers understand how to integrate technology. Thus, the pedagogical, content, and technology aspects are considered when implementing modern and innovative classroom teaching. Teachers must understand the complex interactions among the three core components, PK, CK, and TK, by teaching the material using appropriate pedagogical methods and technology [5].

The TPACK framework also serves as a theory and concept for researchers and educators to measure the readiness of prospective or current teachers to teach effectively using technology. TPACK impacts teachers because they cannot separate the relationship between technology, pedagogy, and content. Therefore, teachers will face more significant challenges in the future, corresponding to technological advancements.

Teachers should actively engage in developing and designing both instruction and curriculum.

Research on Technological Pedagogical Content Knowledge (TPACK) has been conducted by authors [18]. The study reviewed 74 pieces of literature, including journals and articles related to TPACK. The study's results indirectly state that teachers need TPACK for effective classroom teaching, although further research on TPACK is still required. The TPACK framework has a significant impact on teachers and teacher educators. It describes the various types of knowledge teachers need to teach effectively with technology and the complex procedures involved in interacting with this knowledge. Based on data analysis, the TPACK profile of teachers is presented in Table 9.

Table 9 – Scores of Teachers for Technological Pedagogical and Content Knowledge (TPACK)

Question Items	Mean	Std. Deviation	Percentage	Criteria
I can combine technology with the methods used to teach math content	4,2	0,69	84	High
I can evaluate mathematics learning combined with technology based on indicators	4	0,64	80	High
I can connect technology (props/software) to various mathematics content teaching	3,9	0,71	78	Medium
I can choose the suitable media, teaching aids, and applications to solve mathematical problems	4	0,64	80	Medium
I can assess students' work in solving mathematics problems	3,75	0,91	75	Medium
I can prepare to use certain technologies for solving mathematical problems	3,8	0,83	76	Medium
Average	3,94	0,75	78,8	Medium

Based on the average TPACK score, students are in the medium criteria with a score of 78.8%. From these data, we can see that the teacher respondents have a good mastery of material integration, presentation, and use of technology. They can integrate technology into an effective learning process to change how teachers teach and increase student understanding. After we analysed the entire data, we obtained the average results for each aspect of TPACK, which are presented in Figure 2.

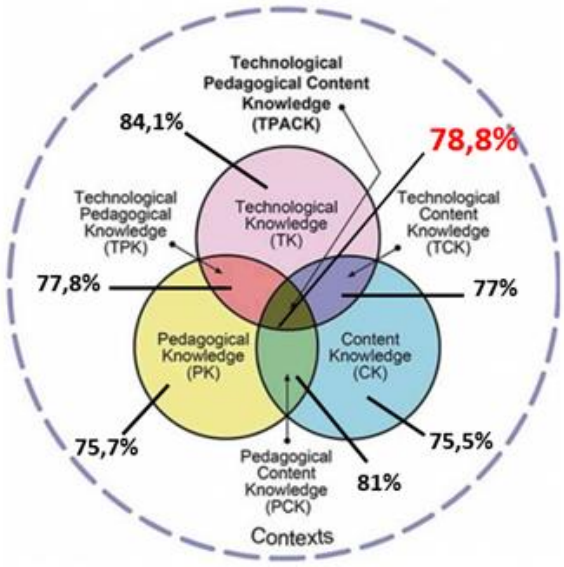

Figure 2 – Average Scores of TPACK Subdomains for Teachers

From Figure 2, it can be seen that TPACK consists of several aspects combined into one. The highest percentage is in the TK aspect, with a score of 84.1%, while the lowest is in CK, at 75.5%. According to research conducted by the author [19], all aspects of TPACK significantly influence the successful integration of TPACK with teaching. TPACK is crucial for the ability to design teaching tools. Teachers can effectively use technology in their teaching activities if they integrate six types of knowledge into the teaching tools they design authors [20]. This study's results are consistent with the research conducted by authors [21], who investigated TPACK abilities in teachers.

Research on TPACK has been conducted by authors [18], who reviewed 74 pieces of literature, including journals and articles related to TPACK.

The study's results indirectly state that teachers need TPACK for effective classroom teaching, although more in-depth research on TPACK is still required. The TPACK framework has a significant impact on teachers and educators. It describes the various types of knowledge teachers need to teach effectively with technology and the complex procedures involved in interacting with this knowledge. According to [22], using technology affects what is taught and when certain teaching materials appear in the curriculum. Therefore, teachers need to ensure that the use of technology is effective. Based on [23] research, some factors that influence a teacher's TPACK ability include the amount of learning experience the government provides to improve teacher quality. Therefore, the length of teaching experience does not directly correlate with increased TPACK abilities.

CONCLUSIONS

Based on the research results and discussion, it can be concluded that the ability of teachers to integrate Technological Pedagogical and Content Knowledge (TPACK) into teaching tools is described as follows: an average standard deviation of 0.75, an average percentage of 78.80%, and an average mean of 3.94, which falls into the medium category.

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