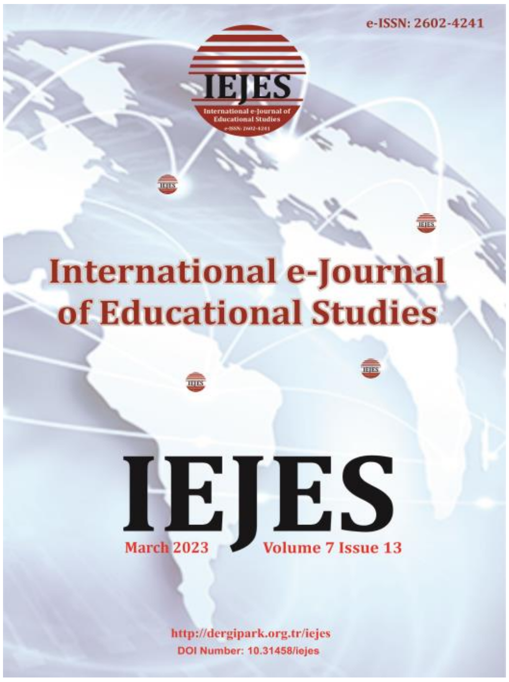

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Abstract

It is one of the important qualifications of teachers to know contemporary instructional technologies and to use them in their lessons. However, the studies have concluded that teachers' use of technological tools and equipment is inadequate and their level of using materials is generally not at a desirable level. In this context, the aim of this study is to determine the level of Technological Pedagogical content knowledge of preservice mathematics teachers in the context of technology-supported activities they prepared. The study was conducted with 13 preservice secondary school mathematics teachers studying at a state university. Preservice teachers were given a training lasting 8 weeks. After the training, they were asked to prepare technology-supported activities including concept cartoon (Powtoon, Canva), concept map (Bubbl.us, Luchidchart), interactive worksheet (Teachermade), gamification applications (Puzzlemaker, Wordwall, Matific, ClassDojo) and digital stories (Pixton, Powtoon, StoryboardThat, Storyjumper). The activities they prepared were analyzed by document analysis method with the Technological Pedagogical Content Knowledge [TPACK] rubric developed by Lyublinskaya and Tournaki (2012) and preservice teachers' TPACK levels were evaluated in terms of purpose knowledge, instructional knowledge, curriculum knowledge and strategy knowledge components. The study has revealed that preservice teachers were able to reach the highest level of discovery, curriculum knowledge was the most successful component and they showed the lowest success in the strategy knowledge component. In this context, we suggest that course content that includes such activity design tasks should be prepared and included in the teaching process for the development of preservice teachers' Technological Pedagogical content knowledge.

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Research Article

Determination of Technology Pedagogy Content Knowledge Levels of Preservice Mathematics Teachers through Activities*

Demet BARAN BULUT [1] **Ebru GÜVELİ** [2]

Abstract

It is one of the important qualifications of teachers to know contemporary instructional technologies and to use them in their lessons. However, the studies have concluded that teachers' use of technological tools and equipment is inadequate and their level of using materials is generally not at a desirable level. In this context, the aim of this study is to determine the level of Technological Pedagogical content knowledge of preservice mathematics teachers in the context of technology-supported activities they prepared. The study was conducted with 13 preservice secondary school mathematics teachers studying at a state university. Preservice teachers were given a training lasting 8 weeks. After the training, they were asked to prepare technology-supported activities including concept cartoon (Powtoon, Canva), concept map (Bubbl.us, Luchidchart), interactive worksheet (Teachermade), gamification applications (Puzzlemaker, Wordwall, Matific, ClassDojo) and digital stories (Pixton, Powtoon, StoryboardThat, Storyjumper). The activities they prepared were analyzed by document analysis method with the Technological Pedagogical Content Knowledge [TPACK] rubric developed by Lyublinskaya and Tournaki (2012) and preservice teachers' TPACK levels were evaluated in terms of purpose knowledge, instructional knowledge, curriculum knowledge and strategy knowledge components. The study has revealed that preservice teachers were able to reach the highest level of discovery, curriculum knowledge was the most successful component and they showed the lowest success in the strategy knowledge component. In this context, we suggest that course content that includes such activity design tasks should be prepared and included in the teaching process for the development of preservice teachers' Technological Pedagogical content knowledge.

Keywords: Mathematics teaching, preservice mathematics teacher, technology supported activity, technological pedagogical content knowledge

1. INTRODUCTION

In order for teachers and preservice teachers to teach effectively in the classroom, they need to acquire skills related to the use of educational technology and to apply and use these skills effectively in the classroom (Varank & Ergün, 2005). It is one of the important qualifications of teachers to know contemporary instructional technologies and to use them in their lessons. In addition, preservice teachers should be able to develop new instructional materials to be used in their lessons or to develop and use existing materials and maintain these competencies when they become teachers. In the study conducted by Köğce, Özpınar, Mandacı-Şahin and Aydoğan-Yenmez (2013), the most emphasized competencies of preservice teachers were "having knowledge on technology, being open to technological innovations and using technological tools well". A good teacher should be competent not only in terms of content knowledge and pedagogical knowledge but also in terms of technological

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pedagogical content knowledge (TPACK). TPACK is a type of knowledge that emerged when Mishra and Koehler (2006) added technology knowledge to the definition of pedagogical content knowledge developed by Shulman (1986). According to this model, three knowledge/competency types, namely technology, pedagogy and content knowledge, interact with each other (Çetin, 2017). Niess (2005) stated that preservice mathematics teachers should take into account four important aspects of the TPACK framework in their technology-assisted instruction. Accordingly, these four components are:

- Knowledge about the purpose of teaching mathematics with technology,
- Students' understanding, thinking and learning knowledge about the outcomes with technology in teaching mathematics with technology,
- Knowledge of curriculum and curriculum materials that enable learning and teaching mathematics with technology,
- Knowledge of representations and teaching strategies to be used for learning and teaching mathematics with technology.

Niess et al. (2009) proposed a developmental model of TPACK. According to this model, mathematics teachers experience a five-stage developmental process while integrating technology into teaching and learning mathematics. The levels of this process are briefly as follows; 1. Recognition (Knowledge) Level: This is the level at which teachers are able to use technology and realize the compatibility of technology with the content of mathematics but are unable to integrate technology into mathematics teaching and learning. 2. Acceptance (Persuasion) Level: This is the period in which teachers' positive or negative attitudes towards the use of appropriate technology in mathematics teaching and learning emerge. 3. Adaptation (Decision) Level: This is the level in which teachers are involved in activities that lead them to accept or reject the choice of appropriate technology for teaching and learning mathematics. 4. Exploring (Application) Level: The level at which teachers actively incorporate technology into mathematics teaching and learning. 5. Developing (Confirming) Level: This is the level at which teachers evaluate the results of the technology they incorporate in the mathematics learning and teaching process (Çetin, 2017).

When we look at the studies on TPACK levels, Lyublinskaya and Tournaki (2012) examined the strategies of preservice teachers that differentiate their lesson plans and teaching with the TPACK rubric they developed. The research revealed that while all preservice teachers had the same differentiation strategies before TPACK, as their TPACK scores improved, their differentiation strategies for their lessons and lesson plans also improved. Akyüz (2016) examined whether 80 preservice teachers reached TPACK level and investigated the effect of students' grade level and teaching method on TPACK. According to the results of the study, it was noted that many preservice teachers did not reach the TPACK level and remained at the level of Technological Content Knowledge (TCK). It was also observed that the teaching method followed, and the grade level of the students were also effective on TPACK. Aydoğmuş and Ibrahim (2022) found in their study that project-based learning significantly increased students' TPACK competencies. Suharwoto (2006), in his study with preservice teachers, found that the four components of TPACK, knowledge of purpose, knowledge of curriculum and curriculum materials, knowledge of teaching strategies, and knowledge of students' learning, understanding and thinking, were at different levels. These different understandings of preservice teachers also affected their teaching. When the course practices of preservice teachers were examined, it was stated that their TPACK development levels were at the level of acceptance, adaptation, exploration and development. In their study, Erdoğan and Şahin (2010) showed that there were significant differences between TPACK sub-dimensions of primary and secondary mathematics teacher candidates. In addition, TPACK levels of preservice teachers explain their achievement levels. Yurdakul (2011) found that preservice teachers' techno-pedagogical education competencies differed according to their ICT usage levels and in parallel with this, as the ICT usage levels of preservice teachers increased, their techno-pedagogical education competencies also increased. In his study, Timur (2011) pointed out that technology-supported instruction helped preservice teachers to develop knowledge of purpose, knowledge of curriculum and curriculum materials, knowledge of instructional strategies and knowledge of assessment, which are subcomponents of TPACK. However, it was found that these teaching practices were not effective on the development of teacher knowledge about students' understanding, thinking and learning, which is another subcomponent. In a study conducted by Balgalmış (2013), it was revealed that there was an increasing change in the TPACK levels of preservice mathematics teachers who planned and implemented mathematics lessons with GeoGebra. The results of the study revealed that technology-supported teaching experience and reflective thinking processes are necessary to improve the TPACK levels of preservice teachers. Mutluoğlu and Erdoğan (2016) examined the TPACK levels of elementary mathematics teachers according to their teaching style preferences. According to the results of the study, TPACK levels of teachers do not vary according to "gender", but they vary according to "seniority" and "technology knowledge". Çetin (2017) examined the change in TPACK competencies and levels of 33 secondary mathematics teacher candidates. Preservice teachers received training on TPACK-based lesson plan preparation, software, site and manipulative use for 6 weeks. Afterwards, they prepared TPACK-based lesson plans. At the end of the process, it was shown that the training they received during the research increased their TPACK development and their ability to integrate technology into their lessons. Valtonen et al. (2019) conducted a study to reveal the development and changes in TPACK of preservice teachers during the first 3 years of teacher education. As a result of the study, it was revealed that teacher education has a positive effect on TPACK. Mailizar, Burg and Maulina (2021) conducted a study on the impact of Online Teacher Professional Development (OTPD) on TPACK of secondary school mathematics teachers. At the end of this study, it was revealed that teachers' TPACK constructs were strongly interconnected and significantly influenced teachers' OTPD. Jin and Schmidt-Crawfor (2022) organized an (educational technology) Edteach course for preservice teachers. This study investigated the difference between TPACK scores of preservice teachers before and after the course. As a result, TPACK scores of preservice teachers increased after the Edteach course. However, there is still a gap between the post-course scores of preservice teachers with low pre-course scores and preservice teachers with high pre-course scores. Following the course, it was determined that there was still a knowledge gap between the groups of preservice teachers. They stated that there is a need for method courses with more specialized content and technology in their studies, applied trainings and field experiences. There is also a need for additional studies that use more research and evaluation criteria to investigate the TPACK development of preservice teachers. According to Agyei and Voogt (2012), in order for preservice teachers to develop their TPACK, they needed to participate in technology-rich design activities (such as basic technology acquisition, technology-supported lesson plans, teamwork and microteaching discussions) and more systematic efforts (such as courses, workshops) were needed for this. This situation highlighted the importance of courses in teacher education programs that include the characteristics of various instructional technologies, their place and use in the teaching process, the development of instructional materials (worksheets, transparencies, slides, video, computer-based course materials, etc.) through instructional technologies, and the evaluation of materials of various qualities. “Instructional Technologies and Material Development” course is one of these courses. The knowledge, attitudes and skills gained in the Instructional Technologies and Material Development course will help teachers to make teaching-learning processes more effective (Tutkun & Koç, 2002). Akkoç, Özmantar and Bingölbali (2008) stated that it would be effective to use TPACK components to diagnose the difficulties of preservice teachers in integrating technology into teaching. They also stated that TPACK framework can be used to determine the content of courses such as “Instructional Technologies in Mathematics Teaching” to be organized for preservice teachers and to create the content of courses on the integration of technology into teaching.

The competence of preservice teachers in the use of instructional technology will be the determinant of being a qualified teacher when they become a teacher. Knowing in which areas they are effective and in which areas they are inadequate will provide solution perspectives with a critical view of the problems. This will help our education system to function more effectively and efficiently and contribute to raising qualified individuals. Preservice teachers who are trained with adequate and effective qualifications will use the teaching material efficiently in their classes. For this reason, it was deemed worth investigating the level of TPACK of preservice teachers in the context of technology-supported activities. In this context, the research question of the study was: "What is the level of technology pedagogy content knowledge of preservice mathematics teachers in the context of technology supported activities they prepared?". This study is also expected to be a source for future studies in the light of developing effective materials, comparing and evaluating materials. In addition, knowing the level of TPACK of preservice teachers at the end of the education they receive in education faculties will contribute to the field. The situations that emerged as a result of this study will be evaluated and suggestions will be presented.

2. METHOD

2.1. Research Design

The study utilized the case study design, one of the qualitative research designs. Case study is defined as a method in which an event or an environment is examined in depth (McMillan, 2004). In research, case study is used to identify and see the details that make up an event, to develop possible explanations for an event, and to evaluate an event (Gall, Borg & Gall, 1996). Due to these characteristics, case study design was preferred in this study conducted to determine the TPACK levels of preservice teachers.

2.2. Participants

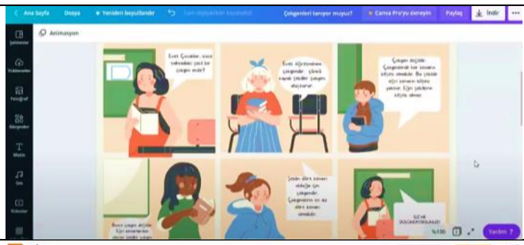
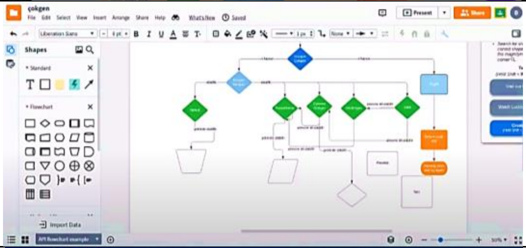
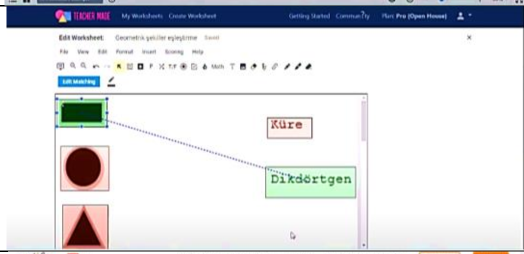
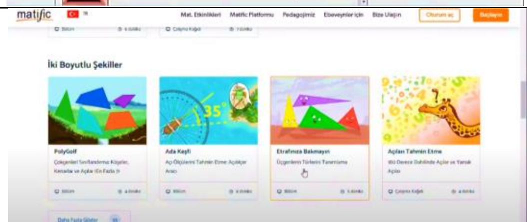
The study was conducted with 13 preservice mathematics teachers studying in the 2nd and 3rd grades at a state university in Türkiye. Criterion sampling method, one of the purposive sampling methods, was used in the selection of preservice teachers. The first criterion for the selection of the participants was that they had basic computer skills and had received computer education before. In addition to this, another criterion was that they had taken the computer-assisted mathematics teaching course. Thus, it was accepted that the preservice teachers had the technology knowledge they would need in the process of designing technology-supported activities.

2.3. Research Process

The permission required for this study was obtained by the Publication Ethics Committee of Recep Tayyip Erdoğan University in Türkiye with the decision numbered 2022/304 on 14.11.2022. The preservice teachers were involved in an 8-week process. In the first two weeks, preservice teachers were presented with the theoretical framework and examples of integrating technology into the teaching process, using and designing activities in mathematics teaching, and designing technology-supported activities in mathematics teaching. In the following weeks, the materials selected within the scope of the research were introduced. The technology-supported materials used in the process, the programs and environments used for the design of these materials, and their visuals are given in Table 1.

Table 1. Research process

Week	Technology Supported Materials	Used programs	Sample Images of the Programs Used
1	Technology integration into the teaching process	-	-
2	Using and designing	-	-

	activities in mathematics teaching		
3	Technology supported activity design in mathematics teaching	-	-
4	Concept Cartoon Introduction	Powtoon, Canva	
5	Concept Map Introduction	Bubbl.us, Luchidchart	
6	Interactive Worksheet Introduction	Teachermade	
7	Introduction of Gamification Applications	Puzzlemaker, Wordwall, Matific, ClassDojo	
8	Digital Story Promotion	Pixton, Powtoon, StoryboardThat, Storyjumper	

Starting from the fourth week, the related programs were introduced to the preservice teachers and the activity design process including technology-supported materials that they could use these programs was carried out. At the end of each week, preservice teachers were individually asked to prepare technology-supported activities to include the learning outcomes in the middle school mathematics curriculum.

2.4. Data Collection Tool

The data group of this study consists of technology-supported activities prepared individually by preservice teachers. Each preservice teacher designed activities in which the learning outcomes in the middle school mathematics curriculum and the relevant material of that week were used. A total of 65 technology-supported activities prepared by preservice teachers were evaluated within the scope of this study and the TPACK levels of preservice teachers were determined. While these activities were being prepared and practiced, there was no restriction on the subject matter and objectives; on the contrary, various activities suitable for the objectives that can be used at the primary education level were introduced, how these activities can be developed and how they can be integrated into the lessons/subjects were taught. The TPACK levels of preservice mathematics teachers were examined in terms of how they use the technology knowledge and technological tools they have acquired through the education they received. This examination is only in TPACK dimension and sub-dimensions such as technology knowledge (TK), pedagogy knowledge (PK), content knowledge (CK), technology pedagogy knowledge (TPK), technology content knowledge (TCK) and pedagogy content knowledge (PCK) were excluded from the examination.

2.5. Data Analysis

Technology-supported activities prepared by preservice teachers were analyzed in the context of TPACK levels by document analysis method. In the evaluation of TPACK levels, the TPACK level rubric developed by Lyublinskaya and Tournaki (2012) was used. In the rubric, the TPACK components that preservice teachers should have are respectively; 1. Determining the purpose 2. 4. Strategy knowledge. These components are evaluated in five stages through the rubric. Within the framework of TPACK defined by Niess (2011), mathematics teachers' performances in integrating technology into their lessons are based on the assessment of each of the components of TPACK that preservice teachers should have at five levels [Recognizing (1), Accepting (2), Adapting (3), Exploring (4) and Developing (5)]. The level ranges of these components vary between 0 and 5 points. The scores written opposite the levels are accepted as an indicator that the preservice teacher is at that level in line with the score received. In order to be at this level, preservice teachers must meet both indicators specified in the rubric. Half scores represent transitions between levels. Accordingly, TPACK components level ranges are given in the table below.

Table 2. TPACK components level ranges

Points Received from Level	Level
0	No level
0,5	Switch to recognition level
1	Recognition level
1,5	Transition from Recognition to Acceptance
2	Acceptance level
2,5	Transition from Accept to Adaptation
3	Adaptation level
3,5	Moving from Adaptation to Discovery
4	Exploration level
4,5	Transition from Exploration to Development
5	Development level

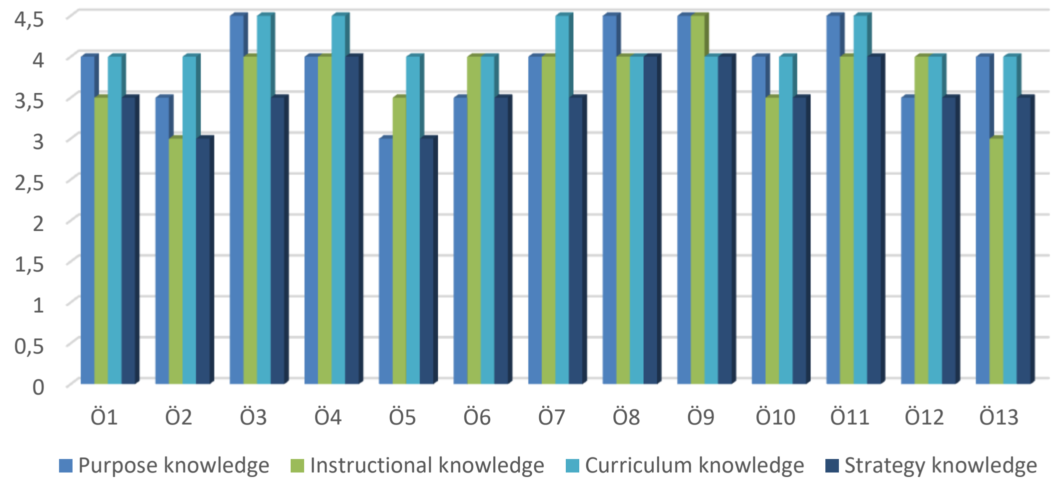
The TPACK level of preservice teachers is determined by the lowest score from the four components. On the other hand, the total scores of the preservice teachers from the four components (Determining the purpose, Teaching knowledge, Curriculum knowledge, Strategy knowledge) in each activity were calculated and their success status in terms of the components in the context of the related activity was interpreted. The highest score that 13 preservice teachers can get in total for each component is 65 and the lowest score is 0. The scores were evaluated with a field expert and a consensus was reached.

3. FINDINGS

In this section, the TPACK levels of preservice teachers were evaluated according to the activities they developed and presented in tables. The evaluation and activity examples for each teaching material are presented in detail.

3.1. TPACK Levels of Preservice Teachers in Concept Cartoon Design

The TPACK levels of preservice teachers in the activities they prepared using concept cartoon are given in Graph 1.



Graph 1. Preservice teachers' TPACK performances in concept cartoon

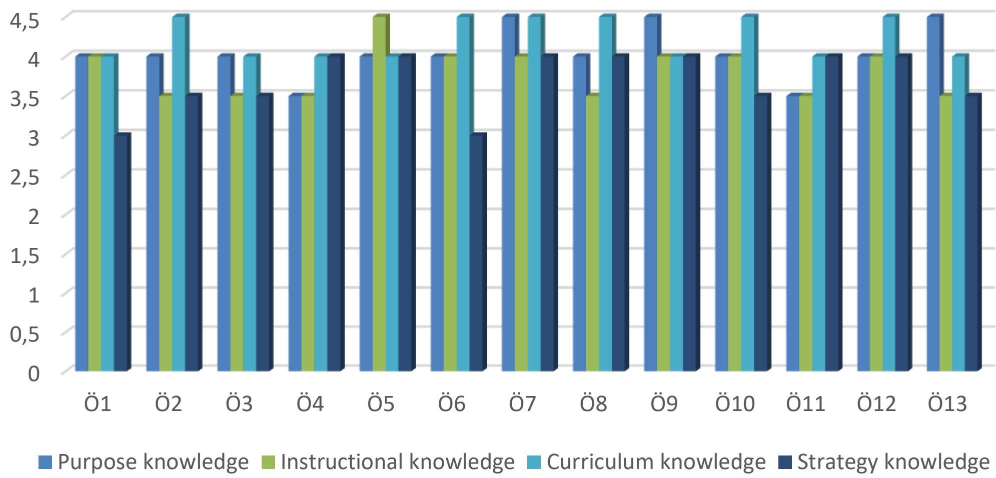
Based on the graph, when the total scores of the preservice teachers for each component were calculated, it was revealed that they scored a total of 44, 42.5, 46 and 40 points for the determination of purpose component, teaching knowledge component, curriculum component and strategy knowledge component, respectively. When the overall evaluation in terms of components was analyzed, it was determined that preservice teachers showed the highest performance in the curriculum knowledge component. The component in which they showed the lowest performance was the strategy knowledge component. When the individual performances of the preservice teachers were analyzed, it was seen that they were at the lowest level of adaptation and at the highest level of transition from exploration to development. When the levels of preservice teachers for four components in the design of concept cartoon material were examined, it was found that T2, T5 and T13 were at the adaptation level; T1, T3, T6, T7, T10 and T12 were at the transition level from adaptation to exploration level; and T4, T8, T9 and T11 were at the exploration level. No preservice teacher reached the development level in the components. The concept cartoons designed by the preservice teachers generally had deficiencies such as not expressing the reasons for misconceptions in the texts in the speech bubbles, the thought forms in the speech bubbles being too long and not expressed in legible sentences, and the use of irrelevant visuals.

An example of the designed concept cartoons is presented below. This concept cartoon was prepared to include the learning outcome "Addition and subtraction with fractions". In addition, misconceptions such as “When adding fractions with unequal denominators, consider the numerator and denominator separately”, "When adding fractions with unequal denominators, do not multiply the numerators while multiplying the denominators by the expansion coefficient while equalizing the denominators" and “When adding fractions with unequal denominators, add the expansion coefficient to the numerator and denominator while equalizing the denominators” were used for the concept cartoon. This material was designed using the Canva tool.

Figure 1. Concept cartoon of T8

3.2. TPACK Levels Of Preservice Teachers in Concept Map Design

The TPACK levels of preservice teachers in the activities they prepared using concept maps are given in Graph 2.



Graph 2. Preservice teachers' TPACK performances on concept map

Based on the graph, when the total scores of the preservice teachers for each component were calculated, it was revealed that they scored 52.5, 49.5, 55 and 48 points for the determination of purpose component, teaching knowledge component, curriculum component and strategy knowledge component, respectively. When the overall evaluation in terms of components was analyzed, it was determined that preservice teachers showed the highest performance in the curriculum knowledge component. The component in which they showed the lowest performance was the strategy knowledge component. When the individual performances of the preservice teachers were analyzed, it was seen that they were at the lowest level of adaptation and at the highest level of transition from the level of discovery to the level of development. When the levels of the preservice teachers for the four components of concept map material design were examined, it was found that T1 and T6 were at the adaptation level; T2, T3, T4, T8, T10, T11 and T13 were at the transition level from adaptation to exploration level; and T5, T7, T9 and T12 were at the exploration level. No preservice teacher reached the development level in the components. The concept maps designed by the preservice teachers had deficiencies such as the map not being detailed enough, not placing the main concept at the center of the map, lack of verbs or conjunctions connecting two concepts between concepts, and the verbs or conjunctions connecting two concepts not being understandable.

An example of the designed concept map is presented below. This material was prepared by T5 using the bubbl.us tool to include the learning outcome "Recognizes rectangle, parallelogram, trapezoid and rhombus; determines angle properties".

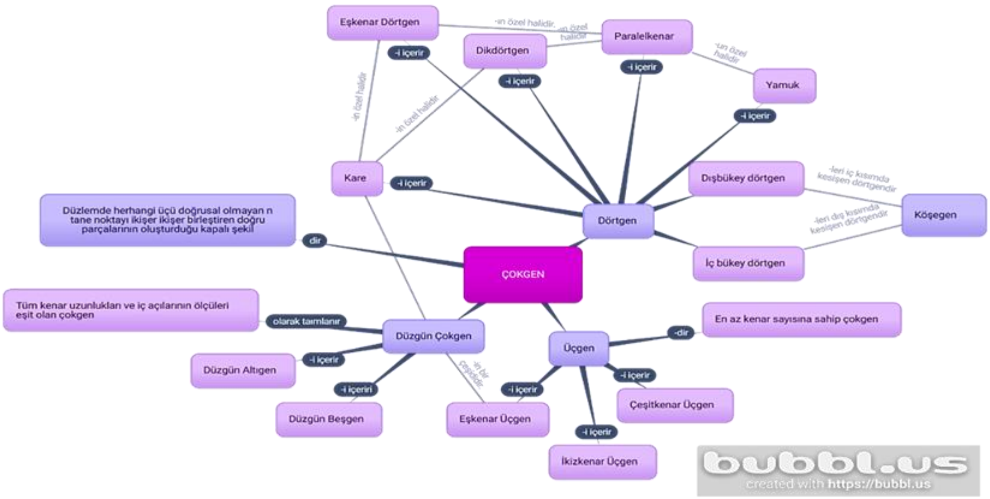
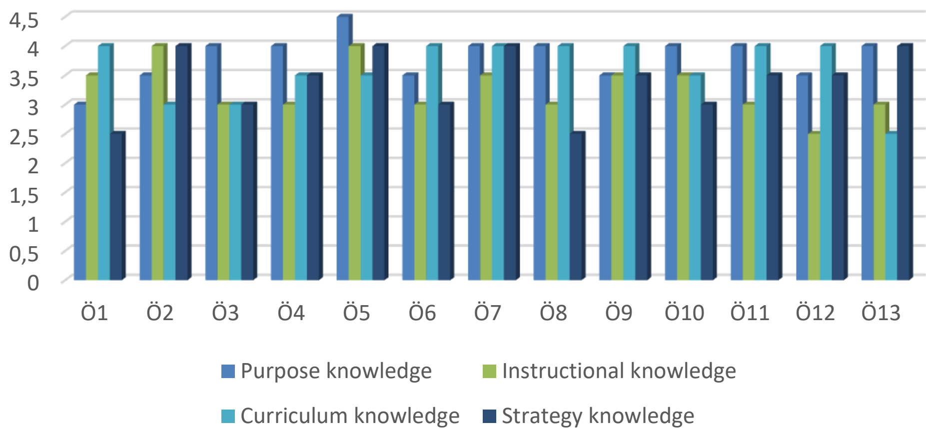


Figure 2. Concept map of T5

3.3. Preservice Teachers' TPACK Levels in Interactive Worksheet Design

The TPACK levels of preservice teachers in the activities they prepared using interactive worksheets are given in Graph 3.



Graph 3. Preservice teachers' TPACK performances on the interactive worksheet

Based on the graph, when the total scores of the preservice teachers for each component were calculated, it was revealed that they scored a total of 43, 35, 40, and 37.5 points for the determining purpose, teaching knowledge, curriculum, and strategy knowledge components, respectively. In terms of the overall evaluation in terms of components, it was determined that preservice teachers showed the highest performance in the determining the purpose component. The component in which they showed the lowest performance was the teaching knowledge component. When the individual performances of the preservice teachers were analyzed, it was seen that they were at the lowest level of transition from acceptance level to adaptation level and at the highest level of transition from adaptation level to exploration level. When the levels of preservice teachers for the four components in the design of interactive worksheet materials were examined, it was found that T1, T8, T12 and T13 were at the level of transition from acceptance to adaptation; T2, T3, T4, T6, T10 and T11 were at the level of adaptation; and T5, T7 and T9 were at the level of transition from adaptation to exploration. There were no preservice teachers who reached the exploration and higher level in the components. In the interactive worksheet designed by the preservice teachers, it was determined that there were deficiencies such as not presenting the information in accordance with the worksheet structure (step by step), not having a hierarchical order in the questions, not reflecting the selected outcome sufficiently in the worksheet, insufficient and inappropriate instructions.

An example of the designed interactive worksheet is presented below. This material was prepared by T7 using Teachermade tool to include the learning outcome "Recognizes right prisms, determines their basic elements, constructs them and draws their angles".

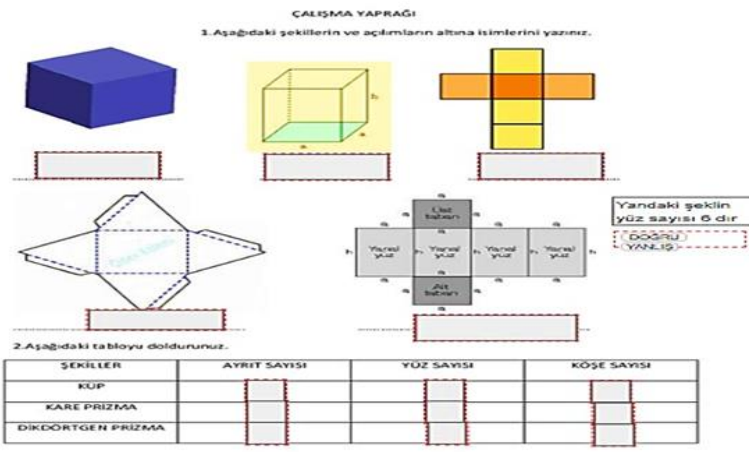
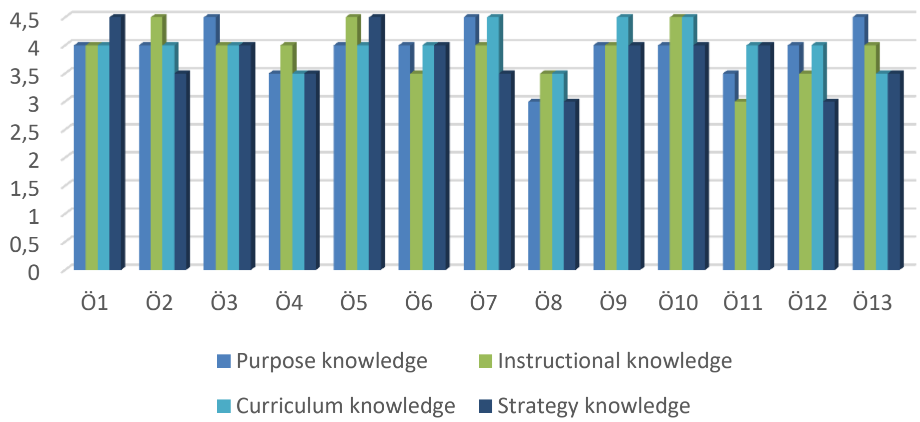


Figure 3. Interactive worksheet of T7

3.4. TPACK Levels of Preservice Teachers in Gamification Application Design

The TPACK levels of preservice teachers in the activities they prepared using gamification applications are given in Graph 4.



Graph 4. Preservice teachers' TPACK performances in gamification applications

Based on the graph, when the total scores of the preservice teachers for each component were calculated, it was revealed that they scored 51.5, 51, 52 and 49 points for the determination of purpose component, teaching knowledge component, curriculum component and strategy knowledge

98

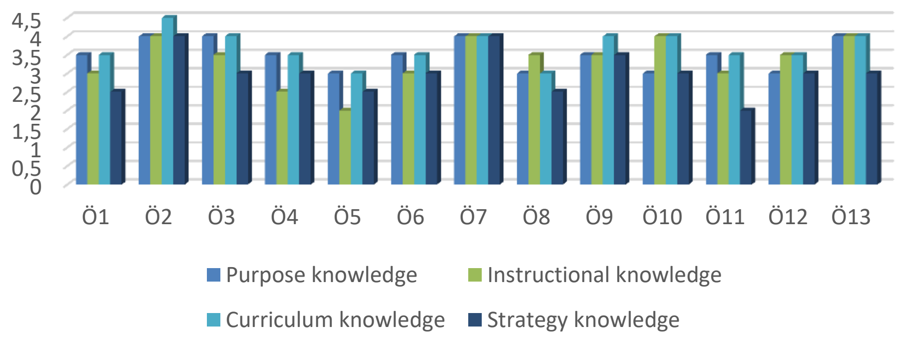
component, respectively. When the overall evaluation in terms of components was analyzed, it was determined that preservice teachers showed the highest performance in the curriculum knowledge component. The component in which they showed the lowest performance was the strategy knowledge component. When the individual performances of the preservice teachers were examined, it was seen that they were at the lowest level of adaptation and at the highest level of exploration. When the levels of preservice teachers for four components in the activity design including gamification application were examined, it was found that T8, T11 and T12 were at the adaptation level; T2, T4, T6, T7 and T13 were at the transition level from adaptation to exploration level; and T1, T3, T5, T9 and T10 were at the exploration level. In this material, there were no preservice teachers who performed above the exploration level for all components. In the gamification applications designed by the preservice teachers, it was determined that there were deficiencies such as the tasks given did not serve the purpose and the tasks for strategy development were limited.

An example of the designed gamification application is presented below. This material was prepared by T10 using the ClassDojo tool to include the learning outcome "Calculates the perimeter lengths of triangles and quadrilaterals and creates different shapes with a given perimeter length". Through this site, various tasks including the related outcome were defined to the students and those who fulfilled the task were given badges and students were given titles such as leader of the week.

Figure 4. Gamification application of T10

3.5. Preservice Teachers' TPACK Levels in Digital Story Design

The TPACK levels of preservice teachers in the activities they prepared using digital story applications are given in Graph 5.



Graph 5. Preservice teachers' TPACK performances in digital story applications

Based on the graph, when the total scores of the preservice teachers for each component were calculated, it was revealed that they scored 45.5, 43.5, 48 and 39 points respectively in the determining the purpose component, the teaching knowledge component, the curriculum component and the

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strategy knowledge component. When the overall evaluation in terms of components was analyzed, it was determined that preservice teachers showed the highest performance in the curriculum knowledge component. The component in which they showed the lowest performance was the strategy knowledge component. When the individual performances of the preservice teachers were analyzed, it was seen that they were at the lowest level of acceptance and at the highest level of discovery. When the levels of the preservice teachers for four components in the design including the digital story were examined, it was found that T5 was at the level of acceptance, T4 was at the level of transition from acceptance to adaptation, T1, T6, T8, T11 and T12 were at the level of adaptation, T2, T3, T7, T9 and T13 were at the level of transition from adaptation to exploration and T10 was at the level of exploration. In this material, there were no preservice teachers who performed above the exploration level for all components. The digital stories designed by the preservice teachers had deficiencies such as the stories did not fully include the learning outcomes, the visuals used did not fully reflect the purpose, there were some limitations in terms of teaching, and there were problems in creating a storyboard.

An example of the designed digital story is presented below. This material was prepared by T2 using the Powtoon tool to include the learning outcome "Construct the area relation of a triangle and solve related problems."

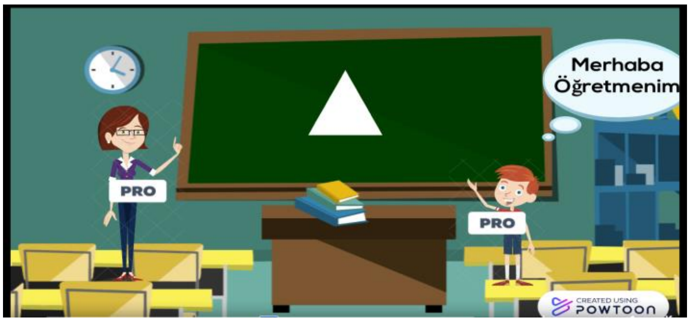

Figure 5. The digital story application of T2

4. DISCUSSION and CONCLUSION

In this study, the TPACK levels of preservice teachers were evaluated within the TPACK framework defined by Niess (2011) within the scope of the technology-supported activities they developed. This assessment is based on the evaluation of their performance in integrating technology into the activities at a five-stage level in each of the four components of TPACK. The performance levels of preservice teachers in each of these components were determined using the rubric of preservice teachers' TPACK level developed by Lyublinskaya and Tournaki (2012).

Concept cartoons are drawings in the form of interesting and surprising cartoons in which each character defends different perspectives on an event or phenomenon in daily life (Keogh & Naylor, 1999; Martinez, 2004). In the activity involving concept cartoons, it was determined that the preservice teachers showed high performance at the level of curricular knowledge. Curricular knowledge means the comprehension of materials and programs that serve as tools especially for teaching. Just as a doctor should know the different treatment methods that can be used to cure a patient, a teacher should know the different curriculum options that can be used for teaching (Öner, 2015). In this context, preservice teachers showed high performance in terms of curriculum knowledge component. This showed that the preservice teachers were successful in choosing which learning outcomes they should choose in accordance with the concept cartoons they used. In all components, preservice teachers were at the lowest level of adaptation and the highest level of transition from exploration to development. This shows that preservice teachers are successful in preparing activities that include activities for discovering and experiencing knowledge, but they have not yet been able to use inquiry learning activities intensively in these activities. The component in which preservice teachers showed the lowest performance was the strategy knowledge component. In this context, preservice teachers did not show high success in terms of the strategies they used in teaching the selected outcomes. This may be attributed to the fact that the preservice teachers have not yet gained experience, have not taken a teaching practice course and have not practiced learning-teaching using technology. The fact that the preservice teachers could not express the reasons for misconceptions clearly and comprehensibly in the texts in speech bubbles in the concept cartoons they designed can be attributed to the fact that they have not yet taken the "Misconceptions" course. The fact that the thought forms in the speech bubbles were too long and not expressed in legible sentences is thought to be due to the deficiencies in the use of mother tongue. The use of irrelevant visuals may be due to the lack of knowledge about instructional technology design. However, the most important issue in concept cartoons is the visuals they use. Dabell (2008) defined a concept cartoon in mathematics teaching as; "The correct answer to a question or problem, distractors and possible wrong answers that can be found are visual arrangements that are prepared in a way to create a discussion environment within the same visual arrangement and enable the student to find the correct answer among all the answers." In his study, Cengizhan (2011) concluded that concept cartoons guide preservice teachers on how to construct knowledge and that cartoons are the most interesting teaching activities and visuals. Therefore, it is important for preservice teachers to overcome this deficiency in concept cartoons.

Throughout the designed activities, technology was used in a structure that focuses on students' understanding of mathematical concepts and can guide students. An example of this is that the structures established in concept maps focus on students' conceptual understanding. For this activity, it was concluded that the preservice teachers showed the highest performance in the curriculum knowledge component. In other words, preservice teachers showed high success in determining the outcomes appropriate to the concept map. In all components, preservice teachers showed the lowest level of adaptation and the highest level of transition from exploration to development. This shows that the activities involving concept maps prepared by preservice teachers enable them to explore and experience knowledge, but do not enable them to use deeper inquiring concepts by using higher level cognitive skills. Hassan, Rosli and Zakaria (2016) developed i-think maps, claiming that concept maps improve higher-order thinking skills, and suggested the creation of a map bank consisting of i-think maps among schools and teachers. The lowest performance was in the strategy knowledge component. Concept maps are concrete graphics that provide a concrete and visual organization of knowledge in the mind and indicate the relationship of a single concept with other concepts in the same category. It is an effective way to schematize the relationships between concepts within units. At the same time, a concept map is a learning and teaching strategy that bridges the gap between how people learn and meaningful learning topics (Kaptan, 1998). However, preservice teachers could not use this strategy adequately. The concept maps designed by the students had deficiencies such as not being detailed enough, not placing the main concept in the center of the map, lack of verbs or conjunctions connecting two concepts between concepts, lack of comprehensibility of verbs or conjunctions connecting two concepts, and insufficient use of cross-connections between concepts. Tuluk (2015) conducted a study to evaluate the angle concept knowledge of preservice secondary school mathematics teachers based on concept maps prepared in a computer-aided environment. At the end of the study, it was revealed that preservice teachers could not establish meaningful relationships in cross-connections in terms of subject area knowledge in the concepts they used while creating concept maps. In our study, in which similar results with this study were observed, it is revealed that preservice teachers should practice more and review their existing conceptual structures.

Looking at the general evaluation in terms of components in the activity involving the interactive worksheet, we found that the preservice teachers showed the highest performance in the component of determining the purpose. In this context, preservice teachers were successful in using appropriate technology procedures. The highest level in the components was the level of transition from adaptation to exploration. In this context, preservice teachers were successful in making associations with technology procedures and using inquiry activities to develop these associations. However, they could not reach the exploration level which involves discovering and experiencing new knowledge. The component in which they showed the lowest performance was the teaching knowledge component. The underlying reason for this is that worksheets are generally used in activities for evaluation purposes rather than for exploration. Kutluca and Baki (2013) concluded that the students found the worksheets instructive and that the computer-assisted worksheets were applicable in teaching. Worksheets give students the opportunity to reflect on the activities carried out in the learning and teaching process, to share and discuss the solutions found (McMillan, 2004). However, it was observed that this situation was not provided in the activities. In the interactive worksheet designed by the students, there were deficiencies such as the fact that the information was not presented in accordance with the worksheet structure (step by step) and there was no hierarchical order in the questions. Worksheets aim to involve all students in the lesson and help them to follow the plan prepared by the teacher by using worksheets, summarize and repeat the topics (Saka et al., 2001). In other words, worksheets are also useful because they attract students' attention and interest and provide the opportunity to follow and evaluate the steps in the implementation process one by one (Yiğit, Akdeniz & Kurt, 2001). However, the preservice teachers ignored this feature of the worksheet and could not use enough steps. Another component in which they performed poorly in this activity was the strategy knowledge component. We found that some preservice teachers could not move away from the traditional teaching approach and only used their own personal learning experiences. In a study conducted by Kılıç et al. (2019) on the TPACK levels of preservice teachers in Türkiye, they stated that approximately 63.51% of the preservice teachers made unscientific explanations about teaching strategies and methods, some of the preservice teachers could not move away from traditional teaching approaches in which technology is used in a teacher-centered way, and some preservice teachers did not know exactly how and how to integrate which technologies into the classroom environment. This study is similar to our study in this regard.

With the developments in technology, the forms and qualities of games are changing. The development of information technologies has brought games everywhere from computers to cell phones, increasing the rate at which they are played. On the one hand, traditional games are being functionally restructured, while on the other hand, new and powerful designs can create any desired environment virtually. This situation leads to the use of games with rich learning environments in the teaching process even more (Akpınar, 1999). In this study, inquisitive tasks were given to students in gamification activities and students were expected to be able to complete these tasks only by concentrating on doing mathematics. One of the tasks given in the gamification applications was related to different ways of calculating the volume of geometric objects. It can be said that preservice teachers who performed successfully in this activity were able to design activities that would develop students' different questioning and reasoning skills. In his study, Çetin (2017) stated that preservice teachers similarly designed technology-supported activities that would improve students' communication, association, etc. skills. Thus, we can say that the activities designed with technology support develop students' skills such as questioning, reasoning and communication. In terms of the overall evaluation in terms of components, we found that the preservice teachers showed high performance in the curriculum knowledge component. The preservice teachers succeeded in using the appropriate topics/outcomes in the mathematics curriculum in preparing games. However, they showed low performance in the strategy knowledge component and could not move away from the traditional approach of using their personal experiences. In terms of level, they could not go beyond the exploratory level in preparing mathematics games that contain deep inquiring conceptual knowledge in which high-level cognitive skills are used in general. According to Li, Lemieux, Vandermeiden and Nathoo (2013) providing preservice teachers with the ability to prepare digital games, which is one of the 21st century skills, can provide them with the opportunity to experience and test pedagogical and technological strategies.

When the overall evaluation in terms of the components of the activity involving digital stories was analyzed, we found that the preservice teachers showed the highest performance in the curriculum knowledge component. The lowest performance was in the strategy knowledge component. The stories designed by the students were found to have deficiencies such as the stories did not fully include the learning outcomes, the visuals used did not fully reflect the purpose, and the selected learning outcomes could not be fully reflected in the story texts from an instructional perspective. Kılıç et al. (2019) determined that although one preservice teacher in their study on TPACK levels was successful in developing digital stories, the other participant preservice teacher had deficiencies in strategy knowledge about technology integration. This preservice teacher could not move away from the traditional approach and stated that she could identify students' learning difficulties with a one-way strategic approach without using technology. In our study, although the preservice teachers performed well in terms of developing or creating stories, they performed poorly in terms of developing strategies appropriate to the subject/outcome. "Teaching Methods and Techniques" and "Material Design" courses are of great importance for preservice teachers to improve these performances and reach a sufficient level. In these courses, it is necessary to include methods and techniques such as "teaching with stories" and for preservice teachers to gain experience and skills. One of the difficulties experienced by preservice teachers is creating a storyboard. In this section, there were deficiencies especially in creating complementary situations. There are studies in the literature with similar results (Çetin, 2021; Karakoyun, 2014)

The preservice teachers themselves chose the practices that they would use in their activities in accordance with their learning outcomes. The aim here is to provide the flexibility of the activities to use the experience and knowledge of the preservice teachers comfortably. In this way, it was seen that the development of their technology knowledge progressed positively during the process of designing the activities. In his study, Timur (2011) provided the preservice teachers with the freedom to choose the software themselves in the process of designing technology-supported mathematics instruction. Thus, he stated that preservice teachers experienced a process that resulted in a positive development in their technology knowledge similar to this study.

As a result, we concluded that although the preservice teachers generally had high level competencies on the basis of the technology-supported activities they designed at TPACK levels, they could not reach the development level, which is the highest level. At the development level, technology should be used in a way to provide students with the deepest conceptual understanding in mathematics and the tasks should include this understanding process. The activities are expected to include inquiry tasks that involve high-level cognitive skills and the use of deep mathematical knowledge representing strategic knowledge. In addition, the activity should be fully compatible with the school curriculum. It is thought that this situation occurred due to the fact that preservice teachers do not yet have full knowledge of curriculum and strategy and have problems in integrating technology.

Suggestions: Experiences are important in raising the TPACK levels of preservice teachers to a higher level. For this purpose, the content of "Material Design in Mathematics Teaching", "Teaching Principles and Methods" and "Misconceptions" courses should be changed in a way to provide preservice teachers with these experiences. In fact, it is important to create the content of the courses in terms of TPACK components in order for preservice teachers to gain competence in this important field. In these courses, preservice teachers should gain more skills related to the use of technology. In addition, in the context of curriculum knowledge, more activities should be done for school mathematics subjects/outcomes, and text reading, story writing and visual design activities should be done for effective use of mother tongue. Teachers should be encouraged and supported in material development. Preparation of materials should be encouraged and efforts should be made to develop them through field competitions, in-service trainings, courses, seminars, success and incentive awards. Teachers should be provided with in-service trainings and their TPACK competencies should be maximized. For this, it is recommended that preservice teachers share a common platform with teachers, which includes concept maps, concept cartoons, digital games, technology-supported worksheets and digital stories. Similar studies can be conducted with different technological tools and software in mathematics and can be done in quantitative dimension.

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