

THE DEVELOPMENT OF LEARNER-CENTERED MATHEMATICS CURRICULUM FOR CULTIVATING MATHEMATICAL PROBLEM-SOLVING SKILLS IN PRIMARY SCHOOL STUDENTS

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Abstract

This article aimed to study (1)The current situation of mathematical problem-solving skills in primary school students; (2)The development of learner-centered mathematics curriculum for cultivating mathematical problem-solving skills in primary school students; (3)The effectiveness of the learner-centered mathematics curriculum for cultivating mathematical problem-solving skills in primary school students. The sample was one classroom (40 students) of fourth-grade students studying in the 2023-2024 academic year of Zhoukou City first primary school located in Henan province in China. They was selected by multi-stage sampling method, the instrument for collecting data was the mathematical problem-solving skills test paper. The researcher reviewed the literature on studies on elementary school students' mathematical problem solving skills, learner-centered approach theories including cooperative learning, problem-based learning and gamification, curriculum development and design theories, and combined the results of interviews with teachers and students to design the learner-centered mathematics curriculum. Descriptive statistics and content analysis were used to analyze the data.

The research results were found as follows: 1) The results showed that the country attaches great importance to cultivating pupils' problem-solving skills. However, current research shows that primary school students have a series of problems in mathematical problem-solving skills, such as weak grasp of basic knowledge, lack of independent thinking and innovation awareness, and insufficient practical operation opportunities. From the perspective of teachers, They are insufficient in cultivating pupils' mathematical problem-solving skills, and there are some problems as follows: outdated teaching concepts, traditional teaching methods, neglect of students' individual differences, undiversified student evaluation methods, and so on. 2) This study integrates three learner-centered teaching techniques, including cooperative learning, problem learning and gamification, to

design diverse activities and encourage students to actively explore and solve problems. The learner-centered mathematics curriculum consists of six components: curriculum principles, curriculum objectives, curriculum content, teaching method, instructional materials and learning evaluation. 3) The learner-centered mathematics curriculum for cultivating mathematical problem-solving skills in primary school students is effective.

Keywords: learner-centered; mathematics curriculum; mathematical problem-solving skills

Introduction

The technological change of the 21st century has put forward new requirements on human ability, and the traditional school education which aims at imparting knowledge and skills is increasingly difficult to meet the social needs (Zhu, 2016). Talents in the new century must not only have the basic learning ability, but also have the ability to use the knowledge they have learned to solve problems. Problem-solving skills are an important ability for people to adapt to the social living environment and promote social innovation and development (Wang, 2021). Step-by-step problem-solving skills are the basis for further learning, rapid adaptation to society and management of personal affairs (Yang, 2016). Cultivating students' problem-solving skills has become the focus of attention in the field of education all over the world (Yang, 2016). Mathematics is a tool for problem solving, communication, reasoning about thought patterns and connecting with other parties (NoprianiLubis et al., 2017). Human civilization is accompanied by mathematics, and every progress of human beings is closely related to mathematics (Zhang, 2020). As an indispensable and important part of education, mathematics education must bear the heavy responsibility of cultivating students' problem-solving skills (Jiang, 2021). Solving mathematical problems is a goal that must be achieved in learning mathematics (Ibrahim et al., 2021). If students' problem-solving skills are low, the instructional goal of having students acquire problem-solving skills that include understanding problems, designing mathematical models, improving models, and interpreting the resulting solutions will be difficult to achieve (Rahmah et al., 2022). Therefore, it is of great significance to develop and improve students' mathematical problem-solving skills.

China has issued a series of documents emphasizing the importance of cultivating students' awareness of problems and innovation in the new curriculum reform. The new mathematics curriculum reform sets the cultivation of problem-solving skills as one of the curriculum objectives of compulsory education (Ministry of Education of the People's Republic of China, 2012). However, the problem-solving skills of Chinese students is not optimistic. The PISA 2012 test conducted by the Organization for Economic Cooperation and Development (OECD) shows that students in Shanghai are better at acquiring knowledge, but lack the ability to apply knowledge (Caixin, 2014). Song (2018) found from his many years of

teaching experience that many elementary school students lack the ability to solve mathematical problems. Zhang (2020) pointed out that "there are three problems in the mathematical problem-solving skills of primary school students: the cognitive bias of mathematical problem-solving skills, the single way of problem representation, and the relatively weak mathematical problem-solving skills." The traditional idea of exam-oriented education is deeply rooted, the effect of the new curriculum reform is not ideal (Shi, 2018). Many school teachers still adopt the traditional indoctrination teaching method, and mainly explain the basic knowledge of mathematics and question types in the classroom. With the rise of grade, mathematics knowledge becomes more and more abstract, and teachers still use traditional teaching methods, which is easy to make students feel boring and lose their enthusiasm and interest in learning mathematics (Yang, 2022). The evaluation only focuses on the test results of students, but does not pay attention to the specific problems of students and the current ability level of students, which is not conducive to the cultivation of students' overall development and personality differences, and it is difficult for students to improve their problem-solving skills qualitatively (Guo, 2020). In the actual teaching process, primary school students rarely can autonomously discover and put forward mathematical problems in the face of practical problems in life situations (Chen, 2022). These phenomena are not conducive to the cultivation of students' learning ability, ability to solve practical problems, ability to explore and innovation ability. How to put "problem solving" into classroom teaching and improve students' problem-solving skills is the focus of this study.

The stage of basic education is the key period to cultivate students' problem-solving skills. Primary school students have the characteristics of strong curiosity and great plasticity, so it is of great significance to carry out research on problem solving skills at this stage. The most effective way to cultivate students' problem-solving skills is to let students "take more responsibility for their work and solve problems by themselves" (Huang & Chen, 2004). Advocates of learner-centered teaching theory believe that "people are born with positive motivation" (Fang, 1990). Learner-centered teaching, also known as the student-centered approach, is "an instructional methodology that uses a student's interests and strengths to create a customized learning experience (Smith, 2022). " Cooperative learning, as one of the learner-centered methods, is very suitable for primary school mathematics classroom, because primary school students are weak in independent learning ability and tend to get tired of learning when they encounter difficult problems, while cooperative teaching has the characteristics of strong autonomy, high openness and fun (J. Chen, 2019). Problem-based learning is a student-centered and problem-oriented teaching method (Wang, 2022), which has a positive impact on the cultivation of problem-solving skills (Valdez & Bungihan, 2019; Wang et al., 2021). Gamification teaching method emphasizes students' whole-class participatory learning, and attaches importance to the playfulness and interestingness of

classroom teaching (C. Chen, 2019). In the teaching process, the gamification teaching method can enable students to learn knowledge in an autonomous and pleasant environment, which is conducive to stimulating students' interest and motivation in learning, and cultivating students' problem-solving skills (Jiang, 2021). In conclusion, learner-centered teaching encourages learners to explore actively, which is conducive to developing students' problem-solving and innovative abilities. It needs a lot of practice and further research to how to effectively use these new learner-centered teaching methods in teaching and fully mobilize students' enthusiasm for learning.

Based on the above reasons, this study aims to develop and design mathematics curriculum with learner-centered concept, guide teachers to change educational concepts, improve teaching methods, fully mobilize students' enthusiasm and initiative in learning, stimulate students' interest in learning, and improve students' problem-solving skills. Researcher believes that it is necessary to develop the learner-centered mathematics curriculum to cultivate students' mathematical problem-solving skills.

Research Objectives

1. To study the current situation of mathematical problem-solving skills in primary school students,
2. To develop the learner-centered mathematics curriculum for cultivating mathematical problem-solving skills in primary school students.
3. To study the effectiveness of the learner-centered mathematics curriculum for cultivating mathematical problem-solving skills in primary school students.

Research Methodology

The researcher divided the development of the learner-centered mathematics curriculum for cultivating mathematical problem-solving skills in primary school students into the following three phases:

Phase 1: Studying the current situation of mathematical problem-solving skills in primary school students

The purpose of this phase is to understand the current situation of mathematical solving skills of primary school students and explore effective cultivating strategies and methods. This will provide key foundational information for the learner-centred curriculum development and design.

The data were collected through research of relevant literature, site visits, and semi-structured interviews with mathematics teachers and students.

Phase 2: Developing the learner-centered mathematics curriculum for cultivating mathematical problem-solving skills in primary school students

This phase first uses the information collected in Phase 1 to design a draft of the learner-centered mathematics curriculum for cultivating mathematical problem-solving skills in primary school students. The draft based on the learner-centered educational concept carefully designs a variety of learning activities, aiming to fully stimulate students' learning interest and initiative and cultivate their ability to solve problems independently. In the classroom teaching, the researchers adopted three learner-centered teaching methods: cooperative learning, problem-oriented learning and gamification, in order to create a positive interactive learning atmosphere and improve the learning effect of students. The components of the curriculum draft consist of: The designed curriculum consists of six components: Curriculum principles; Curriculum objectives; Curriculum content; Teaching method; Instructional materials and Learning evaluation. Mathematics curriculum cover four areas: Numbers and Algebra; Geometry and Graphics; Statistics and Probability; Synthesis and Practice. It contains 4 units in total: Four arithmetic operations; Rectangle and square; Averages and bar charts; Nutrition lunch.

Then five experts evaluated the designed curriculum to assess its effectiveness, that is, the appropriateness and consistency of the content. After collecting the data, the researcher analyzed and evaluated it. The results of the mathematics curriculum appropriateness evaluation showed that the mean score is between 4.2 and 4.8, and the standard deviation is between 0.45 and 0.55, which means the curriculum was appropriate from high level to very high level. The mean scores of the appropriateness which evaluated by a group of experts was higher than 3.51, So the components of an mathematics curriculum had a good quality of appropriateness. The results of the mathematics curriculum consistency evaluation showed that the Index of Item Objective Consistency (IOC) is between 0.6 and 1.0 which were higher than the criteria (0.5). This means that every components of the mathematics curriculum evaluated by experts is consistent with one another.

The curriculum draft was tried out in September 2023 to a classroom (38 students) of Grade 4 in Zhoukou first primary school, to verify the feasibility of the draft curriculum, and to check the accuracy of the wording of the handouts and learning materials. The results show that the draft is feasible, the teaching content and teaching activity design of this course meet the curriculum requirements.

Phase 3: Studying the effectiveness of the learner-centered mathematics curriculum for cultivating mathematical problem-solving skills in primary school students.

The purpose of this phase was to assess the effectiveness of the revised mathematics curriculum as well as to test the feasibility of using the revised mathematics curriculum in real situations. During the implementation of the curriculum, we will record the results of the teaching process and semi-structured interviews with students, and modify the curriculum again based on this feedback.

The mathematics curriculum was implemented with 40 fourth grade students (one classroom of Zhoukou first primary School located in Henan province) to assess the effectiveness of the mathematics curriculum. The experimental design was the one group pretest-posttest design in this phase. The subjects were obtained through the method of multi-stage sampling. They were taught for 11 weeks using a mathematics curriculum developed by the researcher. The data were gathered using the mathematics problem-solving test paper and student semi-structured interview form. The mathematics problem-solving test paper consists of 7 situational items related to the actual situation of life combined with students' knowledge level. Each item is answered in four steps: understanding, analyzing, solving and reviewing, with a full score of 4 in each step. The total scores of skills involved in each step is 28 points. The reliability of the problem-solving test paper was 0.72.

In this study, data were both of quantitative data and qualitative nature. Quantitative data were analyzed by using SPSS and qualitative data were analyzed and interpreted in terms of a descriptive report.

Research Results

Objective 1. The results showed that the country attaches great importance to cultivating pupils' problem-solving skills. However, current research shows that primary school students have a series of problems in mathematical problem-solving skills, such as weak grasp of basic knowledge, lack of independent thinking and innovation awareness, and insufficient practical operation opportunities. From the perspective of teachers, They are insufficient in cultivating pupils' mathematical problem-solving skills, and there are some problems as follows: outdated teaching concepts, traditional teaching methods, neglect of students' individual differences, undiversified student evaluation methods, and so on.

Objective 2. This research integrates three learner-centered teaching techniques, including cooperative learning, problem learning and gamification, to design diverse activities and encourage students to actively explore and solve problems in the process of collaboration. The learner-centered mathematics curriculum consists of six components: curriculum principles, curriculum objectives, curriculum content, teaching method, instructional materials and learning evaluation.

Objective 3. The results showed that the mean scores of the students' mathematical problem-solving skills pretest = 69.83, the standard deviation =12.378, and the mean score of the students' mathematical problem-solving skills post-test =78.28, the standard deviation = 13.778. Specific data was shown in Table 1. In order to further study the changes of students' problem-solving skills before and after participating in learner-centered mathematics curriculum. SPSS Statistics software was used to conduct paired sample T-test on students' mathematical problem-solving skills before and after scores, The results

showed that Mean difference of posttest-pretest test scores =8.450, standard deviation difference =8.482, T value =6.301, $p=.000 < .05$. This indicated that Students who learned through the learner-centered mathematics curriculum had higher mean scores on the posttest for mathematics problem-solving skills compared to their mean scores on the pretest, with a statistically significant difference at the 0.05 level. Specific data was shown in Table 2. Moreover, as shown in the table 1 and 2, the mean scores for the ability to understanding, analyzing, solving, and reviewing were all higher than before, with corresponding t-values of 6.048, 5.674, 4.687, and 5.594, respectively, and the corresponding p-values were all less than 0.05, indicating that the curriculum is also significantly effective in improving various elements of students' mathematical problem solving skills.

Table1 Descriptive statistics results of pretest-posttest
test score for mathematics problem-solving skills

List of evaluation	pre-test		Post-test	
	Mean	S.D	Mean	S.D
Understanding	19.20	3.291	21.40	3.373
Analyzing	18.00	3.195	19.98	3.697
Solving	17.23	3.363	19.23	3.899
Reviewing	15.40	3.011	17.68	3.583
Overall performance	69.83	12.378	78.28	13.778

Table 2 Results of Mathematical problem-solving skills pretest-posttest T-test

Paired posttest-pretest	Mean Difference	S. D. Difference	t	df	p
Understanding	2.200	2.301	6.048	39	.000
Analyzing	1.975	2.201	5.674	39	.000
Solving	2.000	2.699	4.687	39	.000
Reviewing	2.275	2.572	5.594	39	.000
Overall performance	8.450	8.482	6.301	39	.000

Discussions

The research results found that although the country attaches great importance to the cultivation of students' problem-solving skills, the actual training situation is not ideal. Zhang (2020) believes that Students do not have good problem-solving habits, problem-solving ideas and methods are not flexible enough. The teachers lack diversity and

innovation in context creation, outdated teaching mode, can not stimulate students' interest in learning, single teaching methods, insufficient attention to students, simple evaluation language, lack of pertinence (Cao, 2020; Li, 2022; Zhang, 2020).

Shang (2020) 's research results show that curriculum and teaching factors indirectly affect mathematical problem-solving ability by influencing individual factors. Teachers can offer math courses to improve students' problem-solving skills. The most effective way to cultivate students' problem-solving skills is to let students solve problems by themselves" (Huang & Chen, 2004). The learner-centered teaching concept emphasizes the dominant position of students, encourages teachers to fully stimulate students' learning enthusiasm and initiative in the teaching process, and guides them to participate in the solution of practical problems. Based on this principle, the researchers develop reasonable, appropriate and actionable teaching objectives, deeply analyze the characteristics of students, and respect their cognitive development ability. Design interesting and easy to understand course content that incorporates cooperative learning, problem-oriented learning, and gamified teaching methods. This way of teaching allows students to cooperate, communicate and discuss real life problems, and stimulate students' interest in learning through gamification. At the same time, the adoption of diversified learning evaluation has a positive impact on stimulating students' learning interest, promoting students' all-round development and improving teachers' teaching efficiency (Xu, 2018).

The research result show that the use of the learner-centered mathematics curriculum to improve the mathematical problem solving skills of primary school students is effective, and students who have participated in the problem solving instruction training have improved their problem-solving skills. This is consistent with the research results of Shang (2019). According to Wang et al. (2021), students who have received training courses in problem-based learning score higher in their ability to study problem-based learning than students who have not received training. This is because the teaching activities are developed and organized to meet the practical needs of students, and students enjoy learning activities that are fun and useful. Students enjoy participating in teaching, hands-on learning activities. They like to discuss with friends in small groups, exchange ideas and finish homework together. They enjoy teamwork and use teaching methods such as cooperative learning, problem solving, and group discussion. This approach will enable students to engage physically, intellectually, emotionally and socially, with teachers acting as facilitators or advisors.

Conclusion

The mathematical problem solving skills of primary school students need to be improved, and teachers can set up mathematics curriculum to cultivating their problem solving skills. The results of this research provided a learner-centered mathematics

curriculum for cultivating mathematical problem-solving skills in primary school students. The curriculum was developed and designed based on a learner-centered educational philosophy that puts students' interests and needs first, and integrates three teaching techniques - cooperative learning, problem-based learning, and gamification to encourage students to actively solve problems in the collaborative process. The results of curriculum implementing found that after the implementation of the curriculum, the students' mathematical problem-solving skills were higher than the level before the implementation of the curriculum at the statistical significance level of .05.

Suggestions

To ensure the successful implementation of learner-centered mathematics curriculum in the classroom, teachers need to prepare in advance, continuously learn and improve their own teaching practices. By adopting a variety of teaching methods, encouraging students to collaborate and communicate, and implementing strategies such as authentic assessment, teachers can create a positive, interactive and meaningful learning environment for students. Specific suggestions are as follows: 1) Before class, teachers should delve deeply into the course content, objectives, lesson plans and teaching materials to ensure that they have a comprehensive and thorough understanding of the upcoming teaching activities, so as to ensure the smooth and efficient teaching process. 2) Teachers should be proficient in cooperative learning, problem-based learning and gamification methods, so that they can choose the most appropriate teaching methods according to different teaching contents and student groups. 3) In teaching evaluation, teachers should adopt a combination of various evaluation methods, such as observation, oral report, group cooperation and self-evaluation, so as to reflect students' learning results comprehensively and accurately.

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