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Brain-Based Learning Materials and Mathematics Learning Skills of Primary 1 –3 Students

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ABSTRACT

This research aimed to develop brain-based learning materials and mathematics learning skills of primary 1 – 3 students. Its specific objectives were: 1) to create a mathematics learning materials based on brain-based learning for primary 1-3 students in accordance with indicators and learning standards of mathematics curriculum (2017, revised edition), and 2) to evaluate the efficiency of mathematics learning materials by using brain-based learning for the students in primary1-3 in congruence with indicators and learning standards with 3 strands and 5 standard of mathematic curriculum. The samples were 50 students who were studying in the 4th year of mathematics program and they enrolled in the professional teaching experience course and were teaching primary 1-3 at schools located in the remote area of Banna district, Nakhonnayok province. The research instruments consisted of 1) mathematics learning materials with brain development processes to develop mathematical skills, 2) mathematics learning materials creation analysis form, 3) learning materials evaluation form and 4) achievement test. The statistics used for data analysis were percentage, mean, standard deviation, precision, difficulty, discriminatory power and confidence by using the KR20 formula according to Couture Richardson method.

The results indicated that:

1. A mathematics learning materials using brain-based learning for primary 1-3 students in accordance with indicators and learning standards of mathematics curriculum (2017, revised edition) contained 38 activities and learning materials. There were 8 activities / learning materials of students in primary 1, 16 activities / learning materials of primary 2 students and 14 activities / learning materials of 3th primary students.

2. The efficiency evaluation of brain-based mathematics learning materials for students in primary 1-3 in accordance with indicators and learning standards with 3 strands 5 standards of mathematic curriculum by experts found that media performance was very high for students in primary 1, was high level for students in primary 2, and was very high for students in primary 3. The results of the development of mathematical skills in 3 areas which were numerical thinking, problem solving, and intelligence of students in primary 1-3 according to indicators and learning standards with 3 strands 5 standards in mathematics curriculum found that all of students in primary 1-3 had more results of test after the experiment using mathematics learning materials.

1. Introduction

The Ministry of Education announced that the Basic Core Curriculum B.E. 2551 was the national core curriculum of Thailand on July 11, 2008. The curriculum was firstly used in model schools and some schools that were in a ready condition in the year 2009, and was used in all schools in 2010. The Office of Basic Education Commission, by Bureau of Academic Affairs, followed up the results of applying the curriculum in many forms, arranged meeting to gather opinions, conducted observation, and collected reports from offices and organizations related to the curriculum. The results show that most problems with the Basic Core Curriculum B.E. 2551 were found when applying it in schools and classrooms. Furthermore, the study of direction and strategic framework of the 12th National Economic and Social Development Plan (B.E. 2560-2564) happen just right in the period national reformation and rapid changes in global circumstances, the time when nations are more connected than ever. It was produced based on national 20-year strategic framework (B.E. 2560-2579), which is the main plan for developing the country and a part of Sustainable Development Goals (SDGs), National Education Plan B.E. 2560-2579, and the restructuring of Thailand toward 4.0. The main points for translating the plan into practice successfully according to the strategy of human development and potential building is to prepare the workforce and strengthen the potentials of the population in all ages. It should be done by focusing on raising the quality of human capital in a way that is suitable for each age range so that they grow in quality. Development of skills that are consistent with the needs in labor market and skills necessary for living in the 21st Century, as well as raising the standard of education quality toward excellence. Therefore, it is important to drive the national strategy so that the

people can prepare to adjust themselves appropriately when they face the effects from changes. The Basic Core Curriculum B.E. 2551 was modified in mathematics subject group, yet its principle and structure remains the same. The modification mostly focused on updating the content so that it is consistent with the changes and advancement in sciences and knowledge. It was meant to equip learners with what is needed for learning in the 21st Century, making them ready for their future career after graduation or enable them to further their education, compete and live with others the global community. The present framework for improving the curriculum is to provide bodies of knowledge that is universal and not inferior than international level. The learning standards and indicators are adjusted to make them clearer and not overlapping. The subjects in each group are consistent and related with each other. There is good connection between subject groups as well. The content for each grade is arranged base on the level of difficulty so that it is suitable for each age group, and that knowledge and learning process is connected to each other. Students will learn through hand-on practice that sharpen their thinking process. The mathematics subject group (revised version B.E. 2560) based on the Basic Core Curriculum B.E. 2551 contains 3 parts of content and 7 standards. (Office of Basic Education Commission, the Ministry of Education, 2017: 1-4).

Mathematics is one of the most important subjects, a branch of knowledge that has helped human to have a process of thinking systematically and logically. It is also a tool for learning other branches of knowledge. Therefore, mathematics is a significant factor of human development. In order to help students build up competencies specified in the curriculum, one must rely on several factors. The most important one is the learning activities provided by teachers. The teachers must understand the objectives of the curriculum, understand the nature of different problems, and should be able to analyze and solve the problems that occur during classroom sessions. The Ministry of Education suggested some guidelines for arranging learning activities in the use of this curriculum: child as the center of learning process, thinking process, problem solving process, value development process, skill building process, and emphasizing group process Nevertheless, in actual situations, learning activities in mathematics classes have not been consistent with the objectives and the guidelines of the curriculum. This was because most teachers used lecture-base teaching only. They did not encourage or stimulate the students to think. Teachers did not see the importance of lesson plans. Some taught too fast, without recognizing the differences of each individual person. Teachers did not have time to prepare their lessons. Their teaching focused on the outcomes rather than the process. Such learning activities in mathematics classes affected learners in many ways.

For example, learners lack understanding about processes, lack continuity in understanding the lessons, etc. This leads to low quality of mathematics teaching and learning in primary level, not as effective as the curriculum stated. Based on actual learning and teaching activities, academic achievement in mathematics is at unsatisfying level. The results of National Testing (NT) indicate that students' average score, the ability, basic knowledge in numeracy, and reasoning ability. The basic ability in mathematics of learners in Primary 3 from all over the country is lower than 50%, which is the lowest standard. Particularly, the average score of calculation is lower than other aspects. Similar results were also found in Ordinary National Educational Test (O-NET) which indicates that students in Primary 6, Secondary 3, and Secondary 6 have the average score of academic achievement results lower than 50%, which is the lowest international standard. The results of mathematics assessment of learners in TIMSS (Trends in International Mathematics and Science Study) in the year 2011 by IEA (International Association for the Evaluation of Educational Achievement) indicates that Primary 4 and Secondary 2 students in Thailand have the average score of mathematics at low international benchmark, both in content and behaviors. It has been much lower than that the results of other subjects and it has negative effects on the quality of learners and overall education system. (The Institute for the Promotion of Teaching Science and Technology (IPST), 2560 : 4-5)

Phranakhon Rajabhat University is a university that aims at local development according to the royal policy. It has four 20-year strategies (B.E. 2560-2579): Local Development Strategy, Teacher Production and Development Strategy, Education Standard Raising Strategy, and Management System Development Strategy. Local area in under the responsibility of the university consists of 5 districts: 5 districts in Bangkok, Chai Badaan district of Lopburi, the whole province of Nonthaburi and the whole province of Nakhon Nayok. Today, Phranakhon Rajabhat University has made an agreement in making concrete projects with the province of Nakhon Nayok. There are 77 small schools in remote area of Nakhon Nayok. Twenty of these schools are under royal initiative project. A research on developing teachers in remote area of Nakhon Nayok studied the conditions and the needs in teacher development and found that, according to the third quality assessment results by the Office of National Education Standards and Quality Assessment (ONESQA), the aspect that these schools should improve was the lack of self-directed learning skills in students, as well as their love for learning and continuous self-development. It is necessary to build in students the love of reading and the interest to seek knowledge from resources around them and ask questions so to find additional knowledge from researching and reading. They do not show a clear ability in

synthesis analysis and summary of knowledge or experiences. The skill of searching for information through internet and technological media is missing in some grade levels. As for teachers, some schools do not have enough teachers. There are not sufficient teachers to cover every grade level of students. As for the management, some schools still lack all kinds of information technology that make possible self-directed learning, participative learning, and variety of activities based on each learner's interest, as well as class observation and the applying of results to improve learning activities. The school curriculums are still incomplete. Furthermore, from three fieldwork observations, it was found that Kok Sawang School in Baan Na District and Wat Thamaprang School in Pak Plee District, Nakhon Nayok, besides the strengths and the weaknesses which should be developed according to the results of the third external quality assessment by ONESQA, there are additional problems recognized by the research team. For example, most students in the school are problem children. Some come from broken families. Some have parents who work in another province. Some have drug-addicted parents. Some live with their grandparents. The communities near the schools have narcotic drug-use problem. Nevertheless, the main problems seem to be insufficient number of teachers to cover every grade level of students. Hired teachers receive a salary of only 7,000 Baht, which comes from donated money. Sometimes one teacher has to teach all 8 subject groups through the use of eDLTV network which provides valuable teaching resources such as video presentations, worksheets, reading sheets, and quizzes. They are produced by the teachers of Wang Klai Kangwon School in Prachuab Khirikhan and sent through long-distance education satellite. Teachers and students in schools under Information Technology for Education in Remote Area Project give their cooperation in producing the content to be used in e-learning system of long-distance education satellite. National Science and Technology Development Agency is responsible in operating and supervising the service, both off-line and on-line. However, sometimes students cannot catch up with the lessons. Policies related to this matter that schools need to follow often changes, especially in requiring STEM learning activities and requiring teachers to frequently travel to training courses, which means they have to leave their classrooms often. What they need is the media and, if possible, the use of video conference in training or meeting. In addition, there is the lack of administration department staff. One office employee may have to do duties for two schools alternatively week by week. What teachers need most for self-development is how to manage kindergarten level children, knowledge in making mini science projects, and how to make educational media for pre-school level teaching. This is a problem because none of the

teachers there has graduated with a degree in pre-school teaching. In other grade levels, what the teachers need the most is development is the making of educational media for each subject, particularly mathematics, science and English.

From the situations and problems mentioned above, it is necessary to foster and prepare learners to think analytically, think critically, think creatively, solve problems, use technology, communicate, and cooperate when they begin their elementary education. It will help them catch up with the changes in the economic system, society, culture and environment. They will be able to compete and live with the global community. In order to make a mathematics class effective, learners must be prepared to learn many things. Therefore, it is important to arrange learning activities that are suitable for learner's ability and develop many forms of learning activities. It is viewed that brain-based learning is one of the ways that can help students to learn effectively, which will lead to learner's quality being improved. This is why the researcher develops mathematics educational media that is based on brain development process in order to improve mathematic skills of students in Primary 1-3. It will become their foundation and it will strengthen their skills in higher or more advanced lessons. This idea is an additional activity that focuses on using brain-based learning to arrange learning activities, which are used differently from activities in teacher's guidebook. A process of learning that support brain development very well and has good quality for children is learning activity that emphasizes children's participation in arranging and doing activities, both in and out of classroom. This can be done by providing experience, activities, and environment. Giving them new experience is a condition for stimulating children's thinking skills and logical learning in accordance with desired objectives and goals. The learning should be harmonized with the nature of children and their and physical, mental, emotional, social, and intellectual development in each age group. The steps in the learning process are as followed. Step 1, provide real objects or 3-dimension objects as learning media in and outside the classroom so the children can gain experience. Step 2, after learning through real or 3-dimension objects, help the children to move further to the learning process by using their brains imagine or visualize those objects. Step 3, after visualizing picture, move further by allowing the brain to visualize both pictures and their symbols. Step 4, moving away from visualizing and beginning the process of learning through symbols alone (The Office of Basic Education Commission, 2010). Learning mathematics through brain-based approach for students in Primary 1-3 can be applied in providing learning activities for the content and used along with the guidebook for teachers in

mathematics subject group (mathematics for Primary 1-3) in the curriculum. This will make learning activities become more effective.

2. Research Objectives

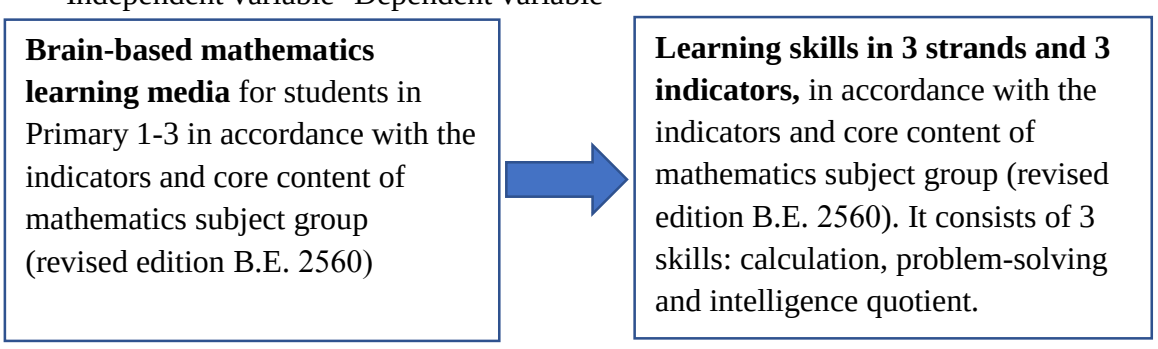
To develop brain-based process for developing mathematics skills in Primary 1-3 students, the specific objectives were:

1. To create brain-based learning media for mathematics subject in Primary 1-3, in accordance with indicators and core content of mathematics subject group (revised edition B.E. 2560)
2. To assess the effectiveness of brain-based mathematics learning media for students in Primary 1-3, in accordance with in accordance with indicators and core content of mathematics subject group, which consists of 3 strands and 5 standards.

3. Benefits of the Research

1. Student teachers can analyze and produce concrete learning media that is suitable for brain development of each age group.
2. Students in Primary 1-3 have brain development in accordance with the indicators and core content of mathematics subject group (revised edition, B.E. 2560)
3. It is beneficial for small schools and students in remote area for they will have learning media for practicing mathematics skills in accordance with the indicators and core content.
4. It can be used to develop learning media for mathematics in other grade level in the future.

4. Research Framework



5. Methodology

1. Producing brain-based mathematics learning media for students in Primary 1-3 in accordance with the indicators and the core content of

mathematics subject group (revised edition B.E. 2560). It can be divided into 2 stages: studying fundamental data and creating mathematics learning media.

Stage 1- Studying fundamental data It is the preparation of fundamental data from document resources related to mathematics learning media development, brain development, mathematics skills, indicators and core content of mathematics subject group (revised edition B.E. 2560) for Primary 1-3, and other related research papers, in order to use as guidelines for creating mathematics learning media.

Stage 2 – Creating mathematics learning media the researcher has followed the principles in learning media production from step 1 to step 5, which includes: 1) Establishing the scope, 2) specifying the objectives, 3) specifying learning activities and media, 4) creating instrument for assessment, and 5) presenting to the experts for checking. The researcher, who is a teacher, and the students in the sample group, whose major is in teaching mathematics subject group, cooperatively analyzed steps 1-3. Together, we established the scope, the objectives, learning activities, and learning media, which consists of 3 strands and 5 standards.

2. Assessment of the effectiveness of brain-based mathematics learning media for students in Primary 1-3, according to the indicators and the core content of mathematics subject group in 3 strands and 5 standards. Here, the researcher conducted step 6 of the principles in learning media production by finding out how effective the learning media was, and then conducted step 7, using the learning media with the target group students for the following purposes

2.1 Find the effectiveness of this form of learning media and improving it. At the step, the researcher used the learning media to find out its effectiveness. Five experts in mathematics were asked to evaluate the effectiveness of the learning media. They consisted of mathematics teachers from Primary 1-3, one from each grade level, a mathematics teacher from secondary level and a mathematics teacher from university level.

A complete evaluation form for assessing the brain-based mathematics learning media for developing mathematics skills of students in Primary 1-3 was provided for the experts. The assessment and improvement of the learning media in each grade level can be divided as followed.

Learning media for Primary 1 – 3 experts in mathematics, which are one mathematics teacher from Primary 1, one mathematics teacher from secondary level, and one mathematics teacher from university level.

Learning media for Primary 1: Three experts in mathematics, which are one mathematics teacher from Primary 1, one mathematics teacher from secondary level, and one mathematics teacher from university level.

Learning media for Primary 2: Three experts in mathematics, which are one mathematics teacher from Primary 2, one mathematics teacher from secondary level, and one mathematics teacher from university level.

Learning media for Primary 3: Three experts in mathematics, which are one mathematics teacher from Primary 3, one mathematics teacher from secondary level, and one mathematics teacher from university level.

2.2 Using the learning media with the target group

The researcher used the learning media with the sample group for experiment. They are the students of Baan Na School in Baan Na District, Nakhon Nayok, in the second semester of the academic year 2019 in order to collect and analyze the data. The process is shown below.

1) Contact the school and ask them the permission to use the brain-based mathematics learning media in experiment with the students in Primary 1-3.
2) Clarify and demonstrate how the learning media should be used to teachers and students in the target group.
3) Give the students a pre-test to check their mathematics skills before using the media.
4) Use the mathematics learning media with the target group students for two months. The teaching was based on the learning process, which is a part of the principles of brain-based learning provided by the Office of Basic Education. Firstly, real objects or 3-dimension objects were used as the media in and outside the classroom in order to give them experience. Secondly, the students began to move away from real or 3-dimension objects to the learning process by asking them to imagine or visualize the objects as mental pictures. Thirdly, the students began to move away from the pictures toward the learning process; their brains were stimulated to see symbols along with the objects. Finally, in the fourth step, they moved away from all pictures and use only the symbols alone.
5) Assess their knowledge after using the mathematics learning media.
6) Analyze, summarize and produce a complete research report.

Creating instrument for assessment

Evaluation form for assessing the learning media

The assessment of the brain-based mathematics learning media to develop mathematics skills in Primary 1-3 students were conducted with the following steps.

1) Study the principles, concepts, and documents related to brain-based mathematics learning media.

2) Create an evaluation form for assessing brain-based mathematics learning media to develop mathematics skills in Primary 1-3 students. The researcher improved the evaluation form by using the principles of learning media effectiveness assessment, teacher's original invention assessment, and invention evaluation form used in job specification. The criteria for evaluating was also specified by using the 4-level method (the Institute for the Promotion of Teaching Science and Technology, 2012: 193)

Mean Intervals	**Opinion Level**
3.50-4.00	Very high
2.50-3.49	High
1.50-2.49	Average
1.00-1.49	Need improvement

3) Present the evaluation form for assessing brain-based mathematics learning media to develop mathematics skills in Primary 1-3 students to the three experts, which consist of 2 mathematics experts and 1 assessment and evaluation expert in order for them to consider content validity of the items used in the evaluation form. It was done by using the criteria for Index of Item-Object Congruence (IOC), which assesses the consistency of the items and the evaluation criteria. If the index is equal to 0.5 or higher, it means that the statement has appropriate language. If the index is lower than 0.5., the evaluation form needs to be improved.

4) Improve and adjust the evaluation form for assessing brain-based mathematics learning media to develop mathematics skills in Primary 1-3 students that has been checked by the three experts. Produce a full and complete version of the evaluation form for assessing brain-based mathematics learning media to develop mathematics skills in Primary 1-3 students.

Achievement Test – It consists of the following steps.

1) Study the curriculum and evaluation theories to establish the objectives of the test.

2) Analyze the content and behavioral purposes

3) Create a mathematics achievement test, ensuring that it covers the indicators and the core content. The test measures 3 mathematics skills: calculation, problem solving and intelligence quotient of students in Primary 1-3, based on the indicators and the core content of mathematics subject group in

3 strands and 5 standards. It was measured according to the learning media, indicators and core content. Each one is about 2-3 items.

4) Check content validity by mathematics experts and assessment & evaluation expert, altogether 3 persons. This is to find the index of item-objective congruence and record the results after the experts checked the test. If the index is equal to 0.5 or higher, the test represents the indicators and the core content of the subject group. If the index is lower than 0.5, then the test should be improved and adjusted.

5) Use the test with Primary 1-3 students of one school, who were not in the sample group, during the second semester of the academic year 2019.

6) Analyze the results to find the value of (R) and (P). The test selected to be used had difficulty level between 0.2-0.8 and the (R) value at 0.2 or higher.

Population and Sample Group

1. The population in this research consisted of 2 groups:

Group 1 – Fifty fourth-year students whose major is mathematics and have registered in Professional Experience in Teaching course.

Group 2 – Nineteen small schools in remote area of Baan Na District, Nakhon Nayok

Reason: The researcher did a fieldwork in a research project on "Teacher Development System in Remote Area: Case Study of Baan Na District in Nakhon Nayok. The results from the third external quality assessment by ONESQA show that the problem that the schools need to solve in terms of students is the lack of analytical thinking, synthetic thinking, creative thinking, critical thinking, judgement, and visions needed to recognize relation of things and solve problems logically in early childhood. As for primary level students, they lack the skill of knowledge seeking, the love of learning and continuous self-development, reading habit, interest in searching for information from resources around them, ask questions and do research to gain additional knowledge from reading. They do not show a clear ability to synthesize, analyze, and summarize knowledge and experience logically. Not every grade level of students can do research through the internet or technological resources. According to the information collected from interviewing the teachers, what most teachers want to develop the most is the producing of learning media for the lessons in all subjects, especially mathematics, science, and English.

2. Sample group in this research

Group 1 – Fifty fourth-year students whose major is mathematics and have registered in Professional Experience in Teaching course.

Group 2 – Nineteen small schools in remote area of Baan Na District, Nakhon Nayok

Reason – The researcher selected 1 school from the 5 schools that were willing and gave permission for mathematics activities to be arranged in the year 2019 (the researcher was able to set up Mathematics Camp in these schools). The one school that was specifically selected is Wat Kok Sawang School in Baan Na District, Nakhon Nayok. Phranakhon Rajabhat University established it as a model school in development and full experimentation with the mathematics learning media can be conducted there.

6. Research Instruments

The following information was gathered from research instruments:

1. The tool used in analyzing activities/ learning media according to the strands, standards, and indicators is the analysis form for the production of mathematics learning media, which consists of strands, standards, indicators, objectives, and activity/learning media.
2. The used in evaluation/assessment
    2.1 Learning media assessment form and guidebook for using
    2.2 Achievement test

7. Data Collection

1. Give teachers and students an orientation before letting them use the learning media so that they have knowledge and understanding of how to use this newly-developed media.
2. Use the mathematics pre-test with the sample group to measure the three skills in mathematics (calculation, problem solving, and intelligence quotient) of Primary 1-3 students in accordance with the indicators and the core content of mathematics subject group in 3 strands and 5 standards.
3. Experiment with the mathematics learning media, which took 2 months to create, by using it both in classroom hours and break times. During the period of using the learning media, the researcher checked the progress, identified the problems that occurred along the way, and recorded them.
4. After using the mathematics learning media for two months, the sample group was asked to do the post-test. They were tested in 3 mathematics skills of Primary 1-3: calculation, problem solving, and intelligence quotient, in accordance with the indicators and the core content of mathematics subject group in 3 strands and 5 standards. The results of pre-test and post-test were then compared, concluded and interpreted.

8. Statistics for Data Analysis

1. Percentage
2. Mean
3. Standard Deviation
4. Validity
5. Difficulty
6. Discrimination
7. Reliability, using Kuder-Richardson Formula 20 (KR20)

9. Conclusion

1st Issue: The production of brain-based mathematics for Primary 1-3 students according to the indicators and the core content of mathematics subject group (revised edition, B.E. 2560) can be divided into 2 stages: studying the fundamental data and producing mathematics learning media.

Stage 1: Studying the fundamental data – The results of producing brain-based mathematics learning media for students in Primary 1-3 in conforming to the indicators and core content of mathematics subject group (revised edition, B.E. 2560) showed that studying the fundamental data and using it as guidelines to create the form of brain-based mathematics learning media can produce the following outcomes. Firstly, the resulted learning media is a real object created specifically for teaching and learning activities. It is beneficial for students' learning experience and can be used in arranging classroom activities to be consistent with the curriculum. Secondly, the learning media is produced according to the brain-based learning principles of Regate and Geoffrey Cain, which state that it is the learning process that can strengthen the development of the brain effectively for children. Learning activities that focuses on participation from students and provides them opportunities to learn both inside and outside classrooms through experiences, activities, and environment will allow them to gain new experience and stimulate their development in logical thinking and learning as stated in the objectives and goals. This learning harmonizes with the nature and the physical, psychological, emotional, social, and intellectual development of children in each age group. Thirdly, the learning media was produced based on the 7 steps principles in learning media production: establishing scope, specifying objectives, specifying activities and learning media, producing assessment tools, presenting to the experts, improving from their suggestions, and using the media with the target group to enhance their all aspects of their skills,

especially their physical development and the learning process of the brain. Fourthly, the learning process is based on the principles of brain-based learning initiated by the Office of the Commission of Basic Education. The first step is to touch actual objects or 3-dimension object. The second step is visualizing the objects as pictures. The third step is to see both pictures and symbols. Finally, the fourth step is the use of symbols alone.

Stage 2: Producing mathematics learning media – The outcome of mathematic learning media production shows that the researcher and the sample group of students use the principles of learning media production to create their work. They analyzed the standards of learning, and the core content of the curriculum to find out suitable topics that should be made into a set of learning media. It was found that the learning media consists of 38 activities: 8 activities for Primary 1, 16 activities for Primary 2, and 14 activities for Primary 3.

2nd Issue: Assessing the brain-based mathematics learning media for Primary 1-3 students in accordance with the indicators and the core content of mathematics subject group in 3 strands and 5 standards. The 6th step is finding out the effectiveness of the learning media. The 7th step is to use the learning media with the target group learners.

2.1 Find out the effectiveness of the learning media and improve it. The results of the assessment of 38 brain-based mathematics learning media activities for Primary 1-3 students shows that the 8 mathematics learning media activities for Primary 1 have overall very high effectiveness (6 activities has very high effectiveness and 2 activities has high effectiveness). When classified into aspects, it was found that the invention received the highest score, followed by the presentation, and design & development. The 16 mathematics learning media activities for Primary 2 have overall high effectiveness. (10 activities have high effectiveness and 6 activities have very high effectiveness). In these number, there are 4 activities that are shared with Primary 1 students. When classified into aspects, it was found that presentation received the highest score, followed by invention, and design & development. The 14 mathematics learning media activities have very high effectiveness (13 activities have very high effectiveness and 1 activity has high effectiveness). When classified into aspects, the invention received the highest score, followed by presentation and design & development, which have equal score.

Table 1: Mean and deviation of effectiveness assessment of brain-based mathematics learning media for Primary 1-3 students, classified by grade level and activities.

Grade / Name of the media	**Comment**		
	$\overline{x}$	**S.D.**	**Level**
Primary 1			
1. Racing Box	3.76	0.48	Very high
2. Equal or Not	3.69	0.47	Very high
3. GEO	3.80	0.40	Very high
4. Hunting for Rainbow Heart	3.64	0.48	Very high
5. Number Sorting)	3.62	0.58	Very high
6. Jumping Number	3.84	0.37	Very high
7. Wheel of figures	3.49	0.63	High
8. Scale of Fate	3.44	0.50	High
Total	**3.66**	**0.51**	**Very high**
Primary 2			
1. Racing Box	3.62	0.56	Very high
2. Equal or Not	3.53	0.50	Very high
3. GEO	3.69	0.47	Very high
4. Hunting for Rainbow Heart	3.33	0.56	High
5. Number Sorting)	3.36	0.48	High
6. Jumping Number	3.33	0.48	High
7. Wheel of figures	3.13	0.63	High
8. Scale of Fate	3.09	0.67	High
1. Racing Box	3.78	0.42	Very High
2. Equal or Not	3.24	0.65	High
3. GEO	3.04	0.77	High
12. Happy Scale	3.51	0.51	Very High
13 Fun Scale	3.31	0.73	High
14. Enjoyable Ball	3.38	0.65	High
15. Which tire can score	3.64	0.53	Very High
16. Enjoyable Graph	3.38	0.58	High
Total	**3.40**	**0.61**	**High**
Primary 3			
1. What your name	3.58	0.66	Very high
2. The winner	3.42	0.62	High
3. Happy Principle	3.51	0.63	Very high
4. Knowledge Millionaire	3.84	0.37	Very high
5. Thinking Table	3.73	0.45	Very high

Grade / Name of the media	Comment		
	$\bar{x}$	S.D.	Level
6. Joyful Train	3.56	0.66	Very high
7. Fun Shopping	3.89	0.32	Very high
8. Fun Clock	3.87	0.34	Very high
9. MATH PUZZLE	3.78	0.42	Very high
10. Forget about the Bear	3.82	0.39	Very high
11. About Bears	3.64	0.57	Very high
12. Measuring Box	3.78	0.42	Very high
13. Geography conquers Symmetry Axis	3.84	0.37	Very high
14. Amazing	3.56	0.62	Very high
Total	**3.70**	**0.52**	**Very high**

Table 2: Mean and standard deviation of the assessment of effectiveness of brain-based mathematics learning media for Primary 1 students, classified by aspect.

Aspects	Opinion		
	$\bar{x}$	S.D.	Level
Content presentation			
1. Suitable with the objectives and the content	3.92	0.28	Very high
2. Suitable with learners	3.83	0.38	Very high
3. Helping learners to understand the content better	3.67	0.48	Very high
4. Able to expand the area of knowledge	3.46	0.59	High
5. Easier for learners to understand	3.50	0.51	Very high
Total	**3.68**	**0.49**	**Very high**
Design and Development			
6. Language and pictures are presented appropriately	3.58	0.50	Very high
7. Size and color of the letters are clear and easy to read	3.46	0.59	High
8. Using attractive modern format and presentation	3.54	0.66	Very high
9. Well-organized	3.75	0.44	Very high
10. Having a good variety and is interesting	3.50	0.66	Very high
Total	**3.57**	**0.58**	**Very high**
Innovation			
11. increasing students' achievement in learning mathematics	3.71	0.46	Very high
12. Modern and easy to learn	3.58	0.50	Very high
13. Having initiative in adapting the media	3.58	0.50	Very high
14. Having potentials to be extended in the future	3.88	0.34	Very high
15. Conforming to morality and academic codes of	3.96	0.20	Very high

conduct			
Total	**3.74**	**0.44**	**Very high**
Grand Total	**3.66**	**0.51**	**Very high**

Table 3: Mean and standard deviation of the assessment of effectiveness of brain-based mathematics learning media for Primary 2 students, classified by aspect.

Aspects	**Opinion**		
	$\bar{x}$	**S.D.**	**Level**
Content presentation			
1. Suitable with the objectives and the content	3.98	0.14	Very high
2. Suitable with learners	3.75	0.48	Very high
3. Helping learners to understand the content better	3.60	0.49	Very high
4. Able to expand the area of knowledge	2.96	0.35	High
5. Easier for learners to understand	3.58	0.50	Very high
Total	**3.58**	**0.54**	**Very high**
Design and Development			
6. Language and pictures are presented appropriately	3.54	0.65	Very high
7. Size and color of the letters are clear and easy to read	3.10	0.59	High
8. Using attractive modern format and presentation	3.02	0.64	High
9. Well-organized	3.67	0.52	Very high
10. Having a good variety and is interesting	2.96	0.65	High
Total	**3.26**	**0.67**	**Very high**
Innovation			
11. increasing students' achievement in learning mathematics	3.58	0.50	Very high
12. Modern and easy to learn	3.10	0.47	High
13. Having initiative in adapting the media	3.17	0.56	High
14. Having potentials to be extended in the	3.27	0.56	High

Aspects	Opinion		
	$\bar{x}$	S.D.	Level
future			
15. Conforming to morality and academic codes of conduct	3.69	0.51	Very high
Total	**3.36**	**0.58**	**High**
Grand Total	**3.40**	**0.61**	**High**

Table 4: Mean and standard deviation of the assessment of effectiveness of brain-based mathematics learning media for Primary 3 students, classified by aspect.

Aspects	Opinion		
	$\bar{x}$	S.D.	Level
Content presentation			
1. Suitable with the objectives and the content	3.66	0.52	Very high
2. Suitable with learners	3.63	0.53	Very high
3. Helping learners to understand the content better	3.64	0.53	Very high
4. Able to expand the area of knowledge	3.62	0.56	Very high
5. Easier for learners to understand	3.73	0.50	Very high
Total	**3.66**	**0.52**	**Very high**
Design and Development			
6. Language and pictures are presented appropriately	3.66	0.56	Very high
7. Size and color of the letters are clear and easy to read	3.70	0.55	Very high
8. Using attractive modern format and presentation	3.66	0.57	Very high
9. Well-organized	3.69	0.55	Very high
10. Having a good variety and is interesting	3.66	0.57	Very high
Total	**3.66**	**0.56**	**Very high**
Innovation			
11. increasing students' achievement in learning mathematics	3.78	0.47	Very high
12. Modern and easy to learn	3.76	0.50	Very high
13. Having initiative in adapting the media	3.80	0.47	Very high
14. Having potentials to be extended in the future	3.89	0.35	Very high
15. Conforming to morality and academic codes of conduct	4.00	0.00	Very high
Total	**3.78**	**0.47**	**Very high**
Grand Total	**3.70**	**0.52**	**Very high**

2.2 Use the learning media with the target group students. The outcomes in the development of the three mathematics skills (calculation, problem-solving, and intelligence quotient) in Primary 1-3 students, in accordance with the

indicators and the core content of mathematics subject group in 3 strands and 5 standards show that almost all the Primary 1 students got higher score in mathematics test after using the mathematics learning media, except for 1 student who received a score lower than the criteria. As for students in Primary 2, most of them received higher score in mathematics, except for 2 students who received a score lower than the criteria. As for students in Primary 3, the results of assessing mathematics learning media show that almost all of the students received higher score after using the learning media, except 1 student who received a score lower than the criteria.

Table 5: Results of the comparison of mathematics score before and after using brain-based mathematics learning media for Primary 1, classified by aspect

Student's Name	Pre-Test Score				Post-Test Score				Amount/Percentage Increase/Decrease			
	Calculation 11 items	Problem-solving 7 items	Intelligence Quotient 7 items	Total 25 items	Calculation 11 items	Problem-solving 7 items	Intelligence Quotient 7 items	Total 25 items	Calculation 11 items	Problem-solving 7 items	Intelligence Quotient 7 items	Total 25 items
1. Thon	2	2	4	8 32%	10	5	4	19 76%	+8	+3	0	+11 44%
2. Phi	2	1	1	4 16%	10	5	6	21 84%	+8	+4	+5	+17 68%
3. Chalee	-absent-				-absent-							
4. Nach	5	3	2	10 40%	7	5	6	18 72%	+2	+2	+4	+8 32%
5. Mon	2	2	1	5 20%	1	5	5	11 44%	-1	+3	+4	+6 24%
6. Wan	4	2	2	8 32%	8	4	6	18 72%	+4	+2	+4	+10 40%
7. Anu	4	4	1	9 36%	5	4	4	13 52%	+1	0	+3	+4 16%
8. Wa	4	4	3	11 44%	6	4	5	15 60%	+2	0	+2	+4 16%
9 Saha	6	0	1	7 28%	8	3	3	14 56%	+2	+3	+2	+7 28%

Table 6: Results of the comparison of mathematics score before and after using brain-based mathematics learning media for Primary 2, classified by aspect

Student's Name	Pre-Test Score				Post-Test Score				Amount/Percentage Increase/Decrease			
	Calculation 11 items	Problem-solving 7 items	Intelligence Quotient 7 items	Total 25 items	Calculation 11 items	Problem-solving 7 items	Intelligence Quotient 7 items	Total 25 items	Calculation 11 items	Problem-solving 7 items	Intelligence Quotient 7 items	Total 25 items
1. Chin	3	4	4	11 37%	3	4	6	13 43%	0	0	+2	+2 7%
2. Thee	6	2	6	14	7	3	10	20	+1	+1	+4	+6

				47%				67%				20%
3. Su	4	2	3	9 30%	7	0	6	13 43%	+3	-2	+3	+4 13%
4. Ad	-absent-				-absent-							
5. Chi	5	2	7	14 47%	10	3	11	24 80%	+5	+1	+4	+10 33%

Table 7: Results of the comparison of mathematics score before and after using brain-based mathematics learning media for Primary 3, classified by aspect

Student's Name	Pre-Test Score				Post-Test Score				Amount/Percentage Increase/Decrease			
	Calculation 11 items	Problem-solving 7 items	Intelligence Quotient 7 items	Total 25 items	Calculation 11 items	Problem-solving 7 items	Intelligence Quotient 7 items	Total 25 items	Calculation 11 items	Problem-solving 7 items	Intelligence Quotient 7 items	Total 25 items
1. Thod	4	1	8	13 43%	3	3	9	15 50%	-1	+2	+1	+2 7%
2. Say	4	2	6	12 40%	6	3	7	16 53%	+2	+1	+1	+4 13%
3. Thi	5	2	3	10 33%	7	4	7	18 60%	+2	+2	+4	+8 27%
4. Song	1	3	6	10 33%	4	2	7	13 43%	+3	-1	+1	+3 10%
5. Orn	5	3	10	18 60%	8	4	10	22 73%	+3	+1	0	+4 13%

Suggestions for future use

1. Teachers should specify an appropriate amount of time and supervise the students closely when they use the brain-based mathematics learning media, until they have a thorough understanding about the media.
2. School directors and teachers may set up coaching activity, in which older students teach younger students to use each learning media. This way, the older students can review what they learn the media.
3. The form and process used in producing this learning media can be applied when producing other learning media for students in higher grade level.

Suggestions for future research

1. A research on producing brain-based mathematics learning media for students in higher grade level should be conducted.
2. A research on developing mathematics learning activities that is suitable with the form of learning in the 21st century, in which mathematics teachers should participate.

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