



Development of mathematics learning management program on fractions for junior high school students with learning disabilities

Porkaew Krutnak^{a,*}, Chanida Mitranun^{b,†}, Tamala Boonyakan^{b,†}

^a Department of Special Education, Faculty of Education, Srinakharinwirot University, Bangkok 10110, Thailand

^b Special Education Development Center, Faculty of Education, Srinakharinwirot University, Bangkok 10110, Thailand

Article Info

Article history:

Received 3 December 2021

Revised 25 February 2022

Accepted 3 March 2022

Available online 12 October 2022

Keywords:

CRA teaching strategy,
fractions,
learning disabilities in mathematics

Abstract

This research aimed to develop a mathematics learning management program on fractions for junior high school students with learning disabilities. The study followed two phases: phase 1, development of the program; and phase 2, trials and improvement of the program. Eight informants were involved in phase 1, who are considered experts, comprising scholars in math, special education, curriculum and instruction, assessment, and education management, with insights also provided by focus groups and content analysis. The program was trialed in phase 2 with 10 junior high school students with learning disabilities from model schools that took part in the inclusive classrooms initiative of the Office of Secondary Educational Service Area, Bangkok Metropolitan Administration, using purposive sampling. The research instruments included: (1) a mathematical learning disorders diagnostic test on fractions; (2) the mathematics learning management program on fractions; and (3) interview recording. The statistics used for data analysis were content analysis and basic statistics. The results were: (1) a mathematics learning management program on fractions for junior high school students with learning disabilities, consisting of program objectives, program features, program participants, learning activities, and measurement and evaluation; and (2) a demonstration of the program efficiency, with (E_1/E_2) yielding scores of 81.40/86.80. The post-training scores of the participating students were higher than their pre-training scores, showing they had better math proficiency with fractions after participating in the program. The effectiveness index (EI) of 0.78 indicated that 78 percent of the students with learning disabilities acquired higher math abilities.

© 2022 Kasetsart University.

* Corresponding author.

E-mail address: porkaewsettapong@gmail.com (P. Krutnak).

† Co-first authors.

E-mail address: chanidam@g.swu.ac.th (C. Mitranun).

E-mail address: tamalaatsatit@gmail.com (T. Boonyakan).

Introduction

Mathematics is a tool for expressing ideas that come from critical and systematic thinking. It empowers rational persons to be able to anticipate and plan their decisions properly with a creative mind as well as equipping them with thorough and careful decision-making and problem-solving skills that are essential for daily life (Office of the Basic Education Commission, 2017). Arithmetic and logical reasoning are the basis of all science and technology and hence mathematics is recognized worldwide as the most important subject in the curriculum of most educational institutions (Suleiman et al., 2019).

Mathematics learning assessment reports on national high school students such as the National Testing (NT), the Ordinary National Education Test (O-NET), the Trends in International Mathematics and Science Study (TIMSS), the program for International Student Assessment (PISA), have shown that junior high school students' scores in Thailand tend to be much lower than the average scores in many other countries in Asia. Furthermore, On average, 15-year-olds scored 419 points in mathematics compared to an average of 489 points in OECD countries (National PISA Operations Center, Institute for the Promotion of Teaching Science and Technology, 2018). In mathematics, if students lack the basic knowledge, it will be hard for them to learn many of the more advanced math topics in high school; for instance, as stated by Witzel and Mize (2018), students with difficulties with fractions will have problems with factors and polynomials.

Undoubtedly, the operation of fractions is challenging for many students, perhaps especially for those with learning disabilities. Due to their learning deficiencies, such students may lack an understanding of basic calculation, number sense, mathematical reasoning, knowledge of numbers and concepts, and the ability to explain mathematical problems related to calculation, and consequently they tend to have poor mathematical-solving skills. Consequently, students academic skills may be lower than other children the same age, causing them problems in school and daily activities (Geary, 2004; Fletcher et al., 2007). They also have problems with estimation and sizes, where they are unable to understand the relationship between numbers (Sharma, 2015). Besides, they may often make errors in calculating addition and division with fractions (Newton et al., 2014), and may not be able to add or subtract fractions with different denominators (Shahbari & Peled, 2017).

Although adding fractions can be taught, even these students will still tend to use and divide fractions incorrectly (Ikhwanudin & Suryadi, 2018). Errors in solving fraction problems also highly affect their ability to perform more advanced calculations (Kim, 2017). Students need more time in solving problems than their peers, even when they have a normal or above-normal intelligence quotient (IQ). Students may have good perceptions and be able to receive normal study in math; however, they may struggle and be less successful (American Psychiatric Association, 2013).

Teaching fractions is a challenging task for math teachers. An analysis of the scores of junior high school students at inclusive schools administered by the Office of Secondary Educational Service Area 2, Bangkok Metropolitan Administration, in an assessment of their abilities by math objectives for the academic years 2018–2019 revealed that students with learning disabilities achieved the lowest scores on fractions. In Thailand, 47 percent of students are mathematically proficient at level 2 or higher. This was consistent with the findings from junior high school math teacher interviews that suggested that fractions were the most problematic topic, yet fractions are critical as the basis for advanced education. Previously, the development of learning achievement on fractions that used skill training for students in general class has proved successful. However, students with learning disabilities in math did not seem to thrive using this solution. Such a finding was not merely because of the students' intellectual abilities, but also their learning process. Teachers need to know and understand students' basic skills in order to find ways to effectively teach students with differences. In the learning process management, help should be rendered fitting the student's learning style (Juithong, 2016). Therefore, teachers need to know, understand, support, and facilitate the learning process in inclusive classrooms along with supplementing various skills' learning that is suitable for all students with regard to their different capacities (Butterworth & Kovas, 2013). As a recognized teaching strategy, differentiated instruction (DI) can respond to students' needs well. Here, students participate in activities that create opportunities for their successful learning (Tomlinson, 2000). The use of suitable learning materials, visual aids, or mathematical models can inspire learning and contribute to successful learning. The organization of learning materials should allow students to truly practice concepts with tangible objects together with having a clear solution to help students understand the concepts more easily (Karagiannakis et al., 2014).

The concrete–representational–abstract (CRA) strategy is a three-step strategy that allows students to conceptualize concrete objects (concrete step) and change them from concrete to semi-concrete through drawing (representational step). Then, in the final stage, they write out mathematical symbols to display a number in pictures (abstract step). This is a very effective teaching system for students with learning disabilities. While each complex math topic may be hard to understand on its own (Milton et al., 2019), with the CRA strategy, students are able to recap and retain knowledge learned well during the performed activities (Strickland, 2014). This strategy is also very effective in giving students a grounding in the concepts for learning fractions (Butler et al., 2003; Reneau, 2012). Watt and Therrien (2016) used CRA in their study to teach fractions to fifth grade students. The learning material used was an area and length model. Comparison of the students' pre-study and post-study exams showed that the students had made more progress through following the CRA strategy. This suggested that CRA was effective for teaching fractions, which was consistent with the finding from Gibbs et al. (2017), who used the CRA strategy to teach elementary students with learning disabilities multiplication by skip counting. The results indicated that the students' skills and abilities regarding their number sense improved. This was also echoed by Strickland (2014), who applied the CRA strategy to secondary students to help them solve mathematical problems based on linear and quadratic equations. The findings showed that the students attained the abilities to learn, calculate, and solve 80 percent – 100 percent of the problems along with greater knowledge retention. So, the use of an appropriate strategy for students with learning difficulties in mathematics could very well help such students develop mathematical abilities.

A mathematics learning management program on fractions (MLMP-F) for students with learning disabilities was developed by the researcher and tested in the present study. Before taking part in the program, students were required to take a diagnostic test on their disabilities prior to joining in the activities, which were designed to suit individual students; thereby following the concept of differentiated instruction (DI). Diverse activities were arranged by the study concept and used concrete learning materials suitable for students with learning disabilities. Measurement and evaluation were also performed and focused on students' study progress. The aim was for students with learning disabilities in mathematics to improve their mathematical abilities

through taking part in the MLMP-F, which would also raise their individual math potential. (Office of Academic Affairs and Educational Standards, 2010).

The findings from the study would also further help the researcher further refine the MLMP-F for junior high school students with learning disabilities to ensure it could help such students develop and improve their mathematical abilities. Further, the research findings would demonstrate the potential of this prototype mathematical learning management program and motivate other teachers to apply it in further learning development for students with learning disabilities in mathematics.

Literature Review

Math Learning Disability

Math learning disability or mathematics disorder or dyscalculia is one of the main learning disabilities, in which students lack the ability to do calculation. They may also have difficulties in math reasoning together with an impaired working memory. They do not understand the concept of numbers or have number sense. They cannot apply mathematical concepts nor can they solve mathematical problems. They may have problems solving simple math; understanding the value of numbers; counting numbers forward or backward; calculating changes; adding, subtracting, multiplying, and dividing by counting fingers; or remembering multiplication (Fletcher et al., 2007). They may not get the meaning of fractions, decimals, or math terminology. They may have difficulties interpreting problems; time concepts; notions of distance, weight, measurement; and quantitative expression. Such problems are likely to show up at the beginning of their study and become even more prevalent in higher levels of classes. Students with learning disabilities in calculation have been estimated to account for 5%–8% of the school-age population, with such children having lower calculation skills than their peers (Magne, 2003; American Psychiatric Association, 2013; Juithong, 2016), even though they may have normal or higher intellectual ability than normal student. Their recognition abilities may be good and they can attend school as normal children. However, they may develop some emotional disabilities and other aspects (Fletcher et al., 2007; Karagiannakis et al., 2014).

Concrete–Representational–Abstract Strategy

One concept used by teachers to enhance their teaching performance is the concrete–representational–abstract (CRA) strategy. This three-step approach helps students to learn and understand concepts one step at a time. Students' abilities to learn and conceptualize are assessed in each stage before moving to the next stage, to eventually complete all three steps, as follows (Riccomini & Witzel, 2009: Step 1. Concrete: Students use concrete, tactile, and three-dimensional learning materials to help them learn and understand a concept and to connect to the next step in the learning approach, Step 2. Representational: Students draw a two-dimensional image to represent the concrete media in Step 1 and to show their understanding of the topic learned and to connect to the next step; and Step 3. Abstract: Students use symbols or mathematical symbols to represent the previous three-dimensional objects and two-dimensional drawings, demonstrating their understanding of the concept (Witzel & Mize, 2018). The CRA strategy aids students with step-by-step conceptualization. The use of shapes, drawings, or illustrations makes it easier for students to understand and have fun. As teaching students with learning disabilities, for each complex topic in mathematics that is hard to understand (Riccomini and Schneider, 2008), students were able to recap and memorize knowledge learned well from the activities. So, CRA has been proven to be effective to use in teaching students and helping them to make progress in mathematics (Strickland, 2014).

Adaptive Learning

Adaptive learning is the process that individual differences are diagnosed and the basic learning environment adapted to match the characteristics and needs of each learner with different learning abilities by taking into account the interests of learners as important (Landa, 1976; Holland, 1977). Learning design process is (1) Analyze learners' ability level; (2) Determine learning objectives; (3) Design learning activities; (4) Design or select appropriate learning materials; and (5) Design Assessment of development-based learning. Adaptive learning consists of examining the learning process and learning product, capable of higher use tools to stimulate learners' potential. Assessment does not emphasize judgment, and does not focus on competition (Wongyai & Pattaphol, 2021).

Methodology

The present research followed two phases, as follows.

Phase 1: Developing A Mathematics Learning Management Program (MLMP) for Junior High School Students with Learning Disabilities

Participants

1. Thirty junior high school students with learning disabilities from model schools taking part in the inclusive classrooms initiative by the Office of Secondary Educational Service Areas 1 and 2, Bangkok Metropolitan Administration, for the academic year 2020.

2. Eight experts, comprising 3 math scholars, 2 special education faculty members, 1 curriculum and instruction specialist, 1 measurement and assessment academic staff member, and 1 education management professional with doctorate degree or special academic standing or at least 10 years of direct expertise.

Research instruments

1. Screening form for persons with learning disabilities secondary level (Ministry of Education, 2014) to apply the mathematical learning disorders diagnostic test on fractions created by the researcher with a content validity (IOC) of 0.80 to 1.00, difficulty rating of 0.20 to 0.83, power of discrimination of 0.20 to 0.73, and reliability of 0.84.

2. Draft MLMP for junior high school students with learning disabilities consisting of: (1) program objectives; (2) program features; (3) program participants; (4) learning activities; and (5) measurement and evaluation.

3. Draft MLMP assessment on fractions for junior high school students with learning disabilities.

Data collection

1. A mathematical learning disorders diagnostic test on fractions was carried out on the 30 junior high school students with learning disabilities who were participating in the research, as above-mentioned. Then the math fault diagnosis test on fractions was taken to test with learning disabilities students at junior high school level inclusive learning model school under the Office of Secondary Education Service Area Bangkok, District 1 and District 2, Academic Year 2020, a total of 30 students. All 30 students had documents, such as a disability card or a medical certificate, certifying learning disabilities.

2. After screening, students with medical evidence, and having tested their basic knowledge of mathematics

for integer knowledge but lacking in fractions as seen from the analysis of the results of the diagnostic test for learning defects in fractions, were admitted to learn with CRA strategies in this program. Then, the information obtained from the fault diagnosis was applied to draft a program for learning management in mathematics on fractions for students with learning disabilities at the lower secondary level, and the quality of the draft program was checked by 5 experts to evaluate the draft program.

3. In the selection of the target group in the creation of diagnostic tests, the students with learning disabilities were screened by each school. The IQ scorers were then screened for those with an IQ greater than 90 (those with learning disabilities must have an IQ > 90). They were then tested. Integer fundamentals selected students who received 80% (integers are the basis of learning fractions). Then a sample group of students with learning disabilities was accepted into the program. An assessment of the draft program was conducted by five experts. The quality of the program was checked by eight experts, using focus group discussion to improve the program according to the recommendations from the experts. Discussion was used to modify the program based on the suggestions of the experts.

Data analysis

Content analysis was conducted using the results from the quality assessment of the draft program and the outcomes from the focus group.

Phase 2: Trials and Improvement of the MLMP-F for Junior High School Students with Learning Disabilities

Participants

1. Ten junior high school students with learning disabilities from model schools taking part in the inclusive classrooms initiative by the Office of Secondary Educational Service Area 2, Bangkok Metropolitan Administration, for academic year 2021, with parents' permission to participate in the research and who had passed the math proficiency test on integer operation created by the researcher as well as completed IQ SPM assessment (Raven, 1998).

2. One math teacher, 1 teaching assistant, 1 mentor for students with disabilities, and 3 educational supervisors, comprising 1 supervisor, 1 school administrator, and 1 teaching supervisor.

Research instruments

1. Mathematical learning disorders diagnostic test on fractions for junior high school students with learning disabilities.

2. MLMP-F for junior high school students with learning disabilities.

3. Interview recording from teachers and all parties involved in the MLMP.

Data collection

1. Permission was asked to collect data for the target schools. Appointments were made to clarify details with the program users.

2. Meetings were scheduled to explain the details with the educational personnel involved with the program. Appointments were made with the parents of the target students to clarify the details and arrange the orientation.

3. The mathematical learning disorders diagnostic test on fractions was used for pre-testing of the target group of students to determine their math learning disabilities on fractions.

4. The results from the mathematical learning disorders diagnostic test on fractions for the target students were analysed. Classes were scheduled following the MLMP at a level appropriate to the mathematical learning disorders of the students as determined from the diagnostic test results.

5. Result notifications were sent for the diagnostic tests and for the appointments with parents and the individual target students for agreeing to the schedules for the students' participation in the program activities.

6. Teachers' program learning was arranged through the CRA strategy prescribed in the learning management plan and program manual, with the learning activities recorded, and a summary of the learning management results was also recorded.

7. Students' post-test results were compared with their pre-test results.

8. Program assessment was conducted via interviews with a supervisor, administrator, teaching supervisor, math teacher, teaching assistant, and mentor for students with disabilities.

Data analysis

The program quality review employed the program efficiency value (E_1/E_2), effectiveness index (EI), and content analysis from the in-depth interviews.

Research Ethics

The researcher's request for ethics consideration for the research project number SWUEC-G 29-/256-E to be conducted on humans, which was approved by the Human Research Ethics Committee, Graduate School, Srinakharinwirot University.

The rights of the target groups were protected by introducing and explaining the research objectives and process to the participants. Their consent and cooperation were requested for the data collection. Information obtained for the research was kept confidential with no harm done to the target groups.

Results

The development of the MLMP-Fs for junior high school students with learning disabilities can be summed up as follows.

1. A quality review of the development of the MLMP-F was carried out by experts through draft program assessment and a focus group. The following is a recap from an analysis of the results.

1.1 The MLMP-F consisted of: (1) program objectives; (2) program features; (3) program participants; (4) learning activities; and (5) measurement and evaluation, as shown in Figure 1 and Figure 2.

The MLMP-F for students with learning disabilities scored an average of 4.75 overall, for which the full scores is 5.00. The average scores were as follows: (1) 4.6 for program components; (2) 4.6 for program objectives; (3) 4.4 for program participants; (4) 5.0 for program features; (5) 4.0 for learning activities; (6) 4.6 for learning management plans; (7) 5.0 for learning materials; (8) 4.6 for measurement and evaluation; and (9) 5.0 for program manual.

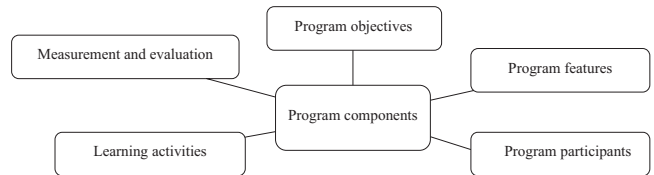


Figure 1 Components of the mathematics learning management program on fractions for students with learning disabilities

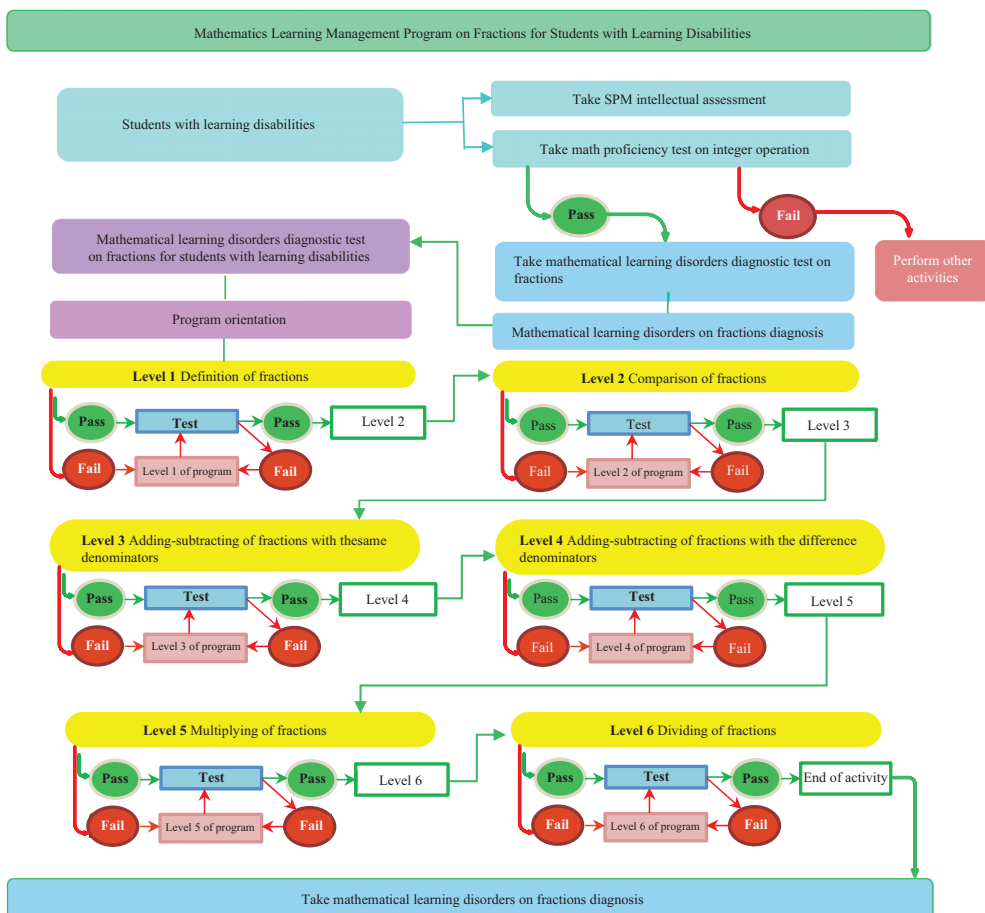


Figure 2 Flowchart for the mathematics learning management program on fractions for students with learning disabilities

Experts' ideas from the focus group suggested that each student with learning disabilities was different. Their math proficiency differed, and hence, the learning management in the program should be organized to suit students' individual skill levels, not a preset one-size-fits-all approach. Measurement and evaluation should employ a variety of methods so that students could learn through their behavioral learning objectives as much as possible.

2. The results from the trials with the MLMP-F for the 10 target students with learning disabilities yielded a program efficiency of 81.4/86.8 and an effectiveness index (EI) of 0.78, as detailed in Table 1.

Table 1 shows the pre-training and post-training effectiveness index (EI) scores for the junior high school students with learning disabilities taking part in the MLMP-F, which was 0.78 or 78.0 percent.

3. The results in terms of the mathematics learning management program improvement on fractions for students with learning disabilities were as follows: (1) The program overview was completed with all the components. The pattern of program learning level applied the complete contents for learning as described by the objectives; (2) The learning management plans were also completed with all the components. The contents covered in the plans were as described by the behavioral objectives; (3) Measurement and evaluation were conducted on the students' abilities covering the learning contents adaptable to the students' learning progress, which were flexible for measuring the students' learning outcomes at each level; (4) The provided learning materials were convenient, strong, and suitable for students' learning. These facilitated student involvement in the activities and practices, which improved their abilities to answer the questions and to take the tests. A variety of learning materials were added to cover more interests; (5) The program manual format was suitable, convenient, easy to read, and clear; and (6) The program was beneficial for users, like the students and teachers. It could also be used as a prototype program for those interested in trying out this program.

More suggestions for applying the program are: (1) The organization of the program in terms of utilizing the students' mathematical learning disorders diagnostic test

results prior to the learning activities was very responsive to the needs of the students with learning disabilities; (2) Meetings with teachers, parents, and students should be held to seek agreement on program participation and to outline the process and objectives; (3) An individualized instruction program (IIP) should be developed in accordance with the program; (4) The use of CRA learning materials must be specified; and (5) An online program manual or guide on using the learning materials and objective test should be provided.

Discussion

1. The mathematics learning management program on fractions for junior high school students with learning disabilities comprised 5 components: (1) program objectives; (2) program features; (3) program participants; (4) learning activities; and (5) measurement and evaluation. The program was developed with efficiency and effectiveness as key aims. For ease of use, a user manual was provided that should be read prior to the program. Also, the experts raised the point that every student with learning disabilities is distinctive, and they do not have the same math proficiency. Therefore, it is necessary to align the program learning management to fit the skill levels of the students. Measurement and evaluation the skill of students used various methods to measure how students were able to learn by considering their behavioral learning objectives. These results were in accordance with the study by Klabpadung (2017), who utilized adaptive learning management to improve the calculating ability of students with learning disabilities through web-based instruction according to students' abilities. This resulted in improving the students' abilities and knowledge retention. Prongsantia (2007) studied the use of a remedial program by forming classes with a small group of students, and found that a higher teaching efficiency was possible than in typical classrooms.

2. The MLMP-F for junior high school students with learning disabilities could be effectively utilized to assist such students. The trials with the target group suggested that students participating in learning activities could use the CRA strategy for developing their math skills and

Table 1 Effectiveness index of the mathematics learning management program on fractions for junior high school students with learning disabilities

(n = 10)						
Number of Students	The sum of the full scores	The total score of the pre-training	The total score of the post-training	Progress	Percent of progress	Effectiveness index : EI
10	500	205	434	229	+45.80	0.78

knowledge of fractions according to their disabilities. This progress was followed through individual appointment schedules based on DI and by applying adaptive learning concepts. Student progress assessment for both pre-training and post-training in the program indicated a program efficiency of 81.4/86.8, which was higher than the 80/80 set criteria with a process (E_1) score of 81.4 and efficiency of products (E_2) of 86.8. Also, the effectiveness index (EI) of the participating students in both the pre-training and post-training tests for the MLMP-F was 0.78, which indicated a 78 percent improvement in their math abilities. This was in line with a study by Dyson et al. (2018) on students' understanding topics like fractions with the same denominators. Their study involved fractions operation for sixth grade students with math problems and used number lines as the learning media. The results from a comparison of the experimental group using the learning materials and a regular group showed that the experimental group students were able to conceptualize fractal calculation immediately after the course and over time became even better than the control group students. This demonstrated the importance of using appropriate learning materials as part of students' conceptualization. This was echoed by Sharp & Shih Dennis (2017), whose study examined the effect of a model drawing strategy (MDS) on assisting fourth grade students when comparing denominators and the order of fractions terms in problem-solving. MDS is a thinking strategy for solving vocabulary problems. Emphasis was put on drawing bar graphs to represent fractions problems. The test results showed that this aid scheme effectively improved fractions problem-solving in students with learning disabilities. This improvement also lasted 2–4 weeks after the initial execution. Moreover, this corresponded to a study conducted by Booth et al. (2014), in which regular tests were used to assess students' abilities after applying MDS to help students with fractions, whereby they were then able to use fraction concepts, and to compare and order fractions in abstract format.

Conclusion and Recommendation

Implications

The program components in the learning activities should be used in accordance with an individualized education plan (IEP) and individualized lesson plan (IIP) for students with learning disabilities. Both documents should be developed by schools, and may be included in

the IEP and IIP filed in the profiles and portfolios of students with learning disabilities.

In the event of a further COVID-19 outbreak, or other major event, some tips and precautions for program use are as follows.

1.1 Strictly prevent the spread of the virus among program users. In the concrete stage of the CRA strategy learning management, 3D learning materials must be used separately by teachers and students. All 3D learning materials should be cleaned every time after use.

1.2 Organize CRA strategy training for parents so they can create learning activities at home and let them take the objective examination at school.

1.3 Organize online learning, and prepare a teaching demonstration video recording the concrete stage, and for reviewing the representational and abstract stages of the CRA learning upon an agreeable schedule conference.

Teachers should prepare the interesting program activities within a daily routine to foster understanding and learning from things the students are familiar with.

Design measurement and evaluation based on each objective in order to assess students' abilities with results judgment of "passing" or "failing" each level by game-based learning (GBL); for example, Kahoot, Baamboozle, Quizizz, and Quizalize. Also, create a user manual to provide a variety of measurement and evaluation options for students with learning disabilities.

Set up a test to assess the retention of knowledge post-program training.

Suggestions for Further Research

Program effects should be studied in a special education center or disability-specific school or welfare school.

The study of the effect of using this program with learning disabilities encountered problems in math.

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowledgments

This research received a scholarship for graduate development year 2021 from the National Research Council of Thailand (NRCT).

References

- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5* (5th ed.). American Psychiatric Association.
- Booth, J. L., Newton, K. J., & Twiss-Garrity, L. K. (2014). The impact of fraction magnitude knowledge on algebra performance and learning. *Journal of Experimental Child Psychology*, 118, 110–118. <https://doi.org/10.1016/j.jecp.2013.09.001>
- Bouck, E. C., Bassette, L., Shurr, J., Park, J., Kerr, J., & Whorley, A. (2017). Teaching equivalent fractions to secondary students with disabilities via the virtual-representational–abstract instructional sequence. *Journal of Special Education Technology*, 32(4), 220–231. <https://doi.org/10.1177/0162643417727291>
- Butler, F., Miller, S., Crehan, K., Babbitt, B., & Pierce, T. (2003). Fraction instruction for students with mathematics disabilities: Comparing two teaching sequences. *Learning Disabilities Research & Practice*, 18(2), 99–111. <https://doi.org/10.1111/1540-5826.00066>
- Butterworth B., & Kovas, Y. (2013). Understanding neurocognitive developmental disorders can improve education for all. *Science*, 340(6130), 300–305. <https://doi.org/10.1126/science.1231022>
- Dyson, N. I., Jordan, N. C., Rodrigues, J., Barbieri, C., & Rinne, L. (2018). A fraction sense intervention for sixth graders with or at risk for mathematics difficulties. *Remedial and Special Education*, 41(4), 244–254. <https://doi.org/10.1177/07419325188071397>
- Fletcher, J. M., Lyon, R. G., Fuchs, L. S., & Barnes, M. A. (2007). *Learning disabilities, first edition: from identification to intervention*. Guilford Press.
- Flores, M. M., Hinton, V. M., & Taylor, J. J. (2018). CRA fraction intervention for fifth-grade students receiving tier two interventions. *Preventing School Failure: Alternative Education for Children and Youth*, 62(3), 198–213. <https://doi.org/10.1080/1045988X.2017.1414027>
- Flores, M. M., Hinton, V. M., & Meyer, J. M. (2018). Teaching fraction concepts using the concrete–representational–abstract sequence. *Remedial and Special Education*, 41(3), 165–175. <https://doi.org/10.1177/0741932518795477>
- Geary, D. C. (2004). Mathematics and learning disabilities. *Journal of Learning Disabilities*, 37(1), 4–15. <https://doi.org/10.1177/00222194040370010201>
- Heacox, D. (2014). *Differentiating instruction in the regular classroom: How to reach and teach all learners* (3rd ed.). Free Spirit Publishing.
- Holland, J. G. (1977). Variables in adaptive decisions in individualized instruction. *Educational Psychologist*, 12, 146–161. <https://doi.org/10.1080/00461527709529170>
- Ikhwanudin, T., & Suryadi, D. (2018). How students with mathematics learning disabilities understand fraction: A case from the Indonesian inclusive school. *International Journal of Instruction*, 11(3), 309–326. <https://doi.org/10.12973/iji.2018.11322a>
- Institute for the Promotion of Teaching Science and Technology. (2018). *PISA summary 2015*. Institute for the Promotion of Teaching Science and Technology.
- Juithong, S. (2016). *The development of learning management model for enhancing the integrated mathematical ability of students with the learning disabilities with different learning styles* [Unpublished doctoral dissertation]. Srinakharinwirot University. [in Thai]
- Karagiannakis, G., Baccaglini-Frank, A., & Papadatos, Y. (2014). Mathematical learning difficulties subtypes classification. *Frontiers in Human Neuroscience*, 8(57). <https://doi.org/10.3389/fnhum.2014.00057>
- Kërënxihi, S. & Gjoci, P. (2017). Involvement of algebraic-geometrical duality in shaping fraction's meaning and calculation strategies with fractions. *Journal of Educational and Social Research*, 7(1), 151–158. <https://www.mcses.org/journal/index.php/jesr/article/view/9738/9376>
- Kim, J. W. (2017). An action research on instruction of division of fractions and division of decimal numbers: Focused on mathematical connections. *Journal of Educational Research in Mathematics*, 27(3), 351–373. <https://www.koreascience.or.kr/article/JAKO201725864505955.page>
- Klabpadung, S. (2017). *Adaptive learning using web-based instruction for calculating ability and retention improvement for children with learning disabilities* [Unpublished master's thesis]. Songkla University. [in Thai]
- Landa, N. L. (1976). *Instructional regulation and control*. Eaglewood Cliffs.
- Magne, O. (2003). *Literature on special educational needs in mathematics: A bibliography with some comments* (4th ed.) (Educational and Psychological Interactions, 124). School of Education.
- Milton, J. H., Flores, M. M., Moore, A. J., Taylor, J. J., & Burton, M. E. (2019). Using the concrete–representational–abstract sequence to teach conceptual understanding of basic multiplication and division. *Learning Disability Quarterly*, 42(1), 32–45. <https://doi.org/10.1177/0731948718790089>
- Newton, K., Willard, C., & Teufel, C. (2014). An examination of the ways that students with learning disabilities solve fraction computation problems. *The Elementary School Journal*, 115(1), 1–21. <https://doi.org/10.1086/676949>
- Office of the Basic Education Commission. (2017). *Guide to the operation of a good school near the home (magnet)*. The Agricultural Cooperative Federation of Thailand. [in Thai]
- Özkan, A., Esra Arikan, E., & Mehmet Özkan, E. (2018). A study on the visualization skills of 6th grade students. *Universal Journal of Educational Research*, 6(2), 354–359. <https://doi.org/10.13189/ujer.2018.060219>
- Prongsantia, S. (2007). *Mathematics remedial program development for children with learning disabilities* [Unpublished doctoral dissertation]. Srinakharinwirot University. [in Thai]
- Reneau, J. L. (2012). *Using the concrete-representational-abstract sequence to connect manipulatives, problem solving schemas, and equations in word problems with fractions*. [Doctoral dissertation, West Virginia University]. <https://doi.org/10.33915/etd.210>
- Riccomini, P., & Witzel, B. S. (2009). *Response to intervention in math*. Corwin.
- Riccomini, P. J., & Schneider, E. (2008). Implementing CRA with secondary students with learning disabilities in mathematics. *Intervention in School and Clinic*, 43(5), 270–276. <https://doi.org/10.1177/1053451208314734>
- Shahbari, J. A., & Peled, I. (2017). Modelling in primary school: Constructing conceptual models and making sense of fractions. *International Journal of Science Mathematics Education*, 15(2), 371–391. <https://doi.org/10.1007/s10763-015-9702-x>
- Sharma, M. C. (2015). A window into dyscalculia and other mathematics difficulties. *The Routledge International Handbook of Dyscalculia and Mathematical Learning Difficulties*, 277. https://perpustakaan.gunungsitolikota.go.id/uploaded_files/temporary/DigitalCollection/ZGUzN2NjODEzODFmOTVmMWYxNDIhZjkyZGI2NWZMDRhZmU2ZDA1Yg==.pdf
- Sharp, E., & Shih Dennis, M. (2017). Model drawing strategy for fraction word problem solving of fourth-grade students with learning disabilities. *Remedial and Special Education*, 38(3), 181–192. <https://doi.org/10.1177/0741932516678823>

- Strickland, T. (2016). Using the CRA-I strategy to develop conceptual and procedural knowledge of quadratic expressions. *Teaching Exceptional Children*, 49(2), 115–125. <https://doi.org/10.1177%2F0040059916673353>
- Strickland, T. K., & Maccini, P. (2013). The effects of the concrete–representational–abstract integration strategy on the ability of students with learning disabilities to multiply linear expressions within area problems. *Remedial and Special Education*, 34(3), 142–153. <https://doi.org/10.1177/0741932512441712>
- Strickland, T. K. (2014). Developing an understanding of quadratics through the use of concrete manipulatives: A case study analysis of the metacognitive development of a high school students with learning disabilities. *Journal of Special Education Apprenticeship*, 3(1), 1–16. <https://files.eric.ed.gov/fulltext/EJ1127897.pdf>
- Suleiman, M. K., Quoreshi, A. M., Bhat, N. R., & Manuvel, A. J. (2019). Species identification of *Vachellia pachyceras* from Kuwait and its relatives *Vachellia gerrardii* and *Vachellia tortilis* based on multilocus plastid gene sequences. *Edinburgh Journal of Botany*, 75, 73–90. <http://doi.org/10.1017/S0960428617000385>
- Tomlinson, C. A. (2000). *Differentiation of instruction in the elementary grades*. <http://education.ky.gov/educational/diff/Documents/tomlin00.pdf>
- Watt, S. J., & Therrien, W. J. (2016) Examining a preteaching framework to improve fraction computation outcomes among struggling learners. *Preventing School Failure: Alternative Education for Children and Youth*, 60(4), 311–319. <https://doi.10.1080/1045988X.2016.1147011>.
- Witzel, B., & Mize, M. (2018). Meeting the needs of students with dyslexia and dyscalculia. *State Journal*, 27(1), 31–39. <https://eric.ed.gov/?id=EJ1166703>
- Witzel, B. S., Riccomini, P. J., & Schneider, E. (2008). Implementing CRA with secondary students with learning disabilities in mathematics. *Intervention in School and Clinic*, 43, 270–276. <https://doi.org/10.1177/1053451208314734>
- Wongyai, W., & Pattaphol, M. (2018). *New horizons of learning to create the future*. Charansanitwong printing.