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ORIGINAL PAPER

Success factors for a national problem-driven program aimed at enhancing affective performance in mathematics learning

Ting-Ying Wang[1] · Fou-Lai Lin[1] · Kai-Lin Yang[1]

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Abstract
Students' negative affective performance in mathematics learning is a global problem, and the situation is especially challenging in high-achieving East Asian countries. Taiwan's Just Do Math (JDM) program was launched to resolve this problem and to serve as an example of successful scaling up with regard to implementation of innovation. We developed a framework consisting of a synthesis of the literature on essentials for successful implementation and for scaling up, and applied this framework for the purpose of identification of the factors contributing to the success of the JDM program. The identified factors include the following: the development of low-complexity sources for teachers' use and the low degree of adaptation required to sustain fidelity; the consideration of characteristics of adopters to promote innovation outside schools; construction of communication channels to ensure the dissemination of the core ideas of JDM; the feedback mechanism through which participating teachers can acknowledge the relative advantages of innovation as realized in the program; the consideration of the influence of historical, social, political, and economic factors on program implementation; and the efforts to ensure teachers' in-depth learning, acknowledgment of the promoted principles, and the sustainability of implementation through implementation of JDM activities in regular mathematics classes.

Keywords Affective performance in mathematics learning · Implementation · Just Do Math · Mathematics grounding activity · Scaling up

1 Introduction

Most regions/countries of East Asia rank high in international comparative studies of mathematics achievement, such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA). However, their education systems are also known for students' low learning motivation, confidence, and valuation of mathematics learning (e.g., Mullis et al., 2020; Organisation for Economic Co-operation and Development (OECD), 2013). Students' negative affective performance in mathematics learning constitutes a global problem. The TIMSS 2019 International Results in Mathematics and Science revealed that more than a quarter of fourth graders in 53% of participating countries do not enjoy studying mathematics and that more than a quarter of eighth graders in 95% of the participating countries are likewise unenthused (Mullis et al., 2020). Thus, research is warranted for the purpose of resolving this problem in the day-to-day practice of mathematics education.

Education research continually seeks to improve education. An increasing number of studies have highlighted the gap between knowledge and practice with regard to effective interventions in this field. A growing body of literature on mathematics education reports the results of research designed to investigate the design, execution, and evaluation of implementation practices and outcomes in response to the need to resolve real-field problems and make on-the-ground improvements (e.g., Maaß & Artigue, 2013; Maass et al., 2019). Taylor et al. (1999) identified prototype development and large-scale replication as the two factors that contribute to successful implementation. They also asserted that considerably more effort is devoted to developing and validating prototypes than to delineating and evaluating scaling up processes. Scaling up remains a significant challenge for implementation stakeholders, especially regarding programs embedding innovative ideas or practices, and some

✉ Fou-Lai Lin
linfl@math.ntnu.edu.tw

[1] Department of Mathematics, National Taiwan Normal University, 88 Sec. 4 Ting-Chou Road, Taipei, Taiwan

have called for evidence-based information in connection with the approach to and evaluation of scaling up (Henderson et al., 2011).

To resolve the problem of negative affective performance in mathematics learning, Taiwan's Ministry of Education launched the Just Do Math (JDM) program in collaboration with Shi-Da Institute for Mathematics Education in 2014. The program involved multiple levels of educational resources and personnel in Taiwan in executing innovative instruction to solve the problem. The scope of the scaling up encompassed more than 23,000 teachers and more than 180,000 primary and lower secondary school students.

The present study investigated the design, execution, and evaluation of the JDM program as a case study to contribute to a research-based understanding of factors contributing to the scaling up implementation of programs. Specifically, the factors that made the JDM program a successful instance of scaling up implementation in improving affective performance in mathematics learning were examined. The following research questions were formulated:

1. How was the JDM program designed, executed, and evaluated in terms of the essential implementation components, and how do the design, execution, and the evaluation contribute to the factors supporting its successful scaling up implementation?
2. What were the changes initiated by the JDM program in terms of the essential implementation outcomes, and how do the changes reflect the factors supporting its successful scaling up implementation?

2 Literature review and conceptual framework

In this section, studies relevant to the approaches for improving affective performance in mathematics learning are presented, serving as the foundation on which the three core ideas of the program were determined. The literature on implementation and scaling up is also discussed as it pertained to developing the framework for analyzing and interpreting the design, execution, and evaluation of JDM.

2.1 Approaches for enhancing affective performance in mathematics learning

Several perspectives in the literature illuminate how to cater to the need to improve affective performance in mathematics learning. Fredricks et al. (2004) argued that appropriate levels of challenge and interest can facilitate the willingness of students to engage in mathematics. Such engagement can also be achieved by providing students with autonomy support—for example, by providing them with choices and sharing with them the authority for decision-making (Attard, 2012). The arrangement of student activities is pertinent to these perspectives. Cavanagh (2011) reported that students' spatiotemporal needs for engaging in self-directed work were met through hands-on activities, small group work, and peer-cooperative and competitive activities in mathematics class.

Regarding the types of student activities conducive to improving affective performance in mathematics learning, researchers have advocated the use of concrete and non-linguistic representations, such as manipulatives, physical movement, and pictographs, when a concept is initially introduced (Furner & Worrell, 2017; Marzano et al., 2001; Thompson & Rubenstein, 2000). Such representations offer possible avenues for students to engage in mathematics, and support student learning as concrete references and aids for the retrieval of mathematics concepts (Mix, 2010). Researchers have also suggested gamifying activities to increase learning motivation and engagement as well as confidence in mathematics learning, because gamification is associated with students' innate psychological needs, including autonomy, competence, and relatedness (Ryan et al., 2006; Watson-Huggins & Trotman, 2019).

Three factors have been identified regarding improving students' affective performance in mathematics learning (Wang & Hsieh, 2016). The activity factor is relevant to students' needs for autonomy and peer relatedness, and the extrinsic motivation factor is related to students' need to facilitate positive relationships with their teachers. Approaches based on these two factors were associated with the earlier discussion on enhancing affective performance. Approaches related to the remaining factor, the cognitive factor, aim to fulfill students' needs for understanding and competence development. For example, teachers should consider how well students comprehend instruction, explain the purpose of learning a new mathematical concept, and provide challenges and immediate feedback to students regarding their learning. This factor reminds us to acknowledge student cognition in the context of enhancing affective performance in mathematics learning, especially in a society where the principles of traditional Confucian education—specifically, academic achievement—remain highly valued (Leung, 2006).

The findings discussed thus far provide foundations for the three core ideas of JDM: (C1) helping students develop fundamental prerequisite mathematical ideas before they learn in regular classes as opposed to providing remedial instruction after they encounter failure; (C2) helping students construct concrete references for mathematical concepts through the operation of manipulable representations; and (C3) helping students increase their mathematics learning motivation through activity gamification (Lin, 2013).

2.2 Implementation and scaling up

The intention to resolve educational problems in practice has resulted in the advocacy for implementation research, through which researchers and stakeholders in implementation delivery (e.g., administrators, practitioners, instructors, and students) can jointly contribute to the examination of the process and the optimization of the results (Fixsen et al., 2005). However, the factors that lead to successful implementation have not been comprehensively addressed. Taylor et al. (1999) affirmed that the two factors involved in implementation success are prototype development and large-scale replication. To evaluate program implementation, Fixsen et al. (2005) further created a conceptual framework containing five essential components and three essential outcomes. The first essential component is a *source*, indicating a composite of the original practice that best exemplifies the features of attempted implementation. The second component, *destination*, refers to the participants who adopt the implementation resources. The third component is *communication links*, which refers to the set of within-program implementation drivers to ensure fidelity and favorable effects on implementation. The fourth component, a *feedback mechanism*, involves the collection of a regular flow of reliable information to guide decision-making. The fifth component, *influence*, entails the consideration of the influence of social, economic, political, historical, and psychosocial factors on implementation. The three essential outcomes are changes in practitioners' professional behaviors, changes in organizational structures and cultures to support practitioners' professional behaviors, and changes in relationships among practitioners, including stakeholders, receivers, and program partners.

The literature on scaling up further indicates the characteristics of these essential components and outcomes that should be considered to reflect the factors that contribute to successful implementation. Rogers (2003) identified four factors influencing the scaling up of the implementation of innovative practice, namely, innovation attributes, communication channels, adopter characteristics, and adaptation. *Innovation attributes* refer to (a) a *relative advantage* over current alternatives that can substantially change educational outcomes, (b) *compatibility* with existing values and needs, (c) *low complexity* in the understanding and implementation of innovations, (d) *high trialability* of innovations at low cost, and (e) *observability* of the benefits of the innovations. The second factor, *communication channels*, suggested the existence of intermediates as interpersonal channels between innovators in programs and the broad practitioners. These intermediates can help expand innovation by sharing their implementation experience and sustaining fidelity when scaling up. The third factor is *adopter characteristics*, the understanding of which helps enroll, maintain, and increase the number of program participants, which is necessary for innovative implementation before a self-sustaining spread can be achieved (Foote et al., 2014). The fourth factor, the *role of adaptation*, can range from top-down diffusion with a low degree of adaptation to horizontal network diffusion with a high degree of adaptation. Innovation-related implementations tend to employ top-down approaches by providing a package of ready-to-go materials to promote high fidelity (Foote et al., 2014; Henderson & Dancy, 2008).

In the scaling up context, Coburn (2003) argued that beyond an increase in the number of program practitioners, the extent to which the core principles of the program are upheld should be highlighted. As the four factors that characterize effective scaling up implementation, she identified the following: depth; sustainability; the spread of norms, principles, and beliefs; and a shift in reform ownership. *Depth* is similar to the concept of maintaining fidelity through a low degree of adaptation, and *sustainability* is comparable to the concept of creating a self-sustaining spread with regard to understanding adopter characteristics. The *spread of norms, principles, and beliefs* emphasizes the dissemination of the innovative ideas or standards within the program along with the activity structures or materials. A *shift in reform ownership* indicates the change in the responsibility to enact and sustain innovative implementation from program innovators to local districts, schools, or teachers—representing a shift from external to internal reform.

Synthesis of the aforementioned literature on the essentials for successful implementation and factors supporting scaling up implementation contributed to the formation of the present conceptual framework for analyzing and interpreting the design, execution, and evaluation of JDM to explore the factors contributing to its successful scaling up implementation (see Fig. 1).

3 Methodology

We collected various types of data from various levels of the JDM program. We first briefly introduce the program in Sect. 3.1 to facilitate understanding of the data collection and analysis.

3.1 Program design and execution

The implementation of the JDM program involved teacher or student learning activities in four fields to which multiple levels of personnel contributed, namely, primary and secondary school students and teachers as well as university-level teacher educators. At the core of the program were mathematical grounding activity (MGA) modules, reflecting the three core ideas C1, C2, and C3 (see Sect. 2.1). MGAs were so named because they stemmed essentially from these

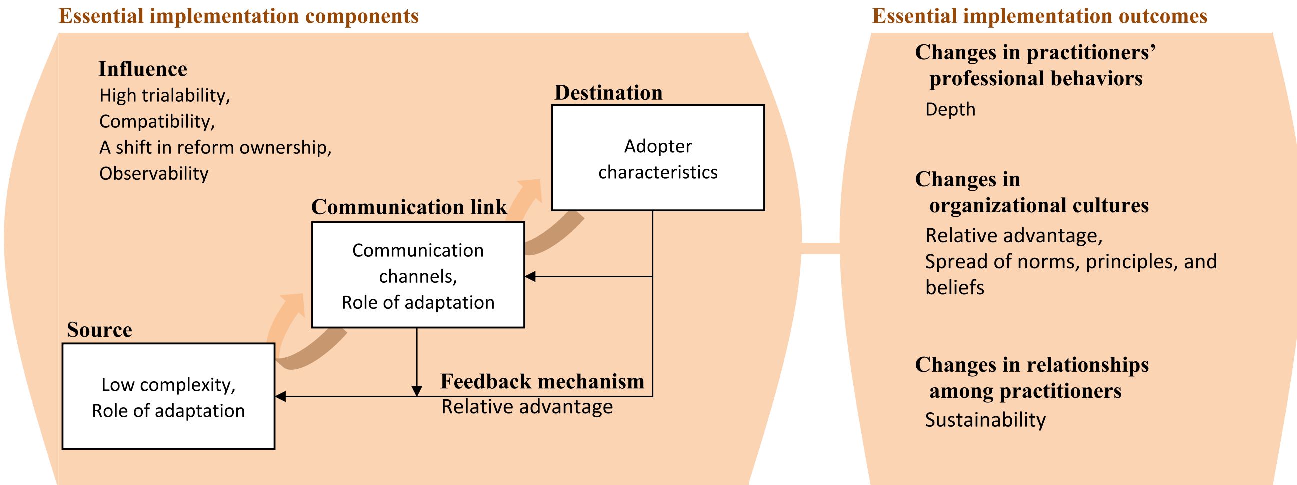


Fig. 1 Factors supporting scale-up applied to essentials for successful implementation (color figure online)

goals, in order to instill fundamental mathematical concepts in students as prerequisites to and the basis for regular mathematics learning. The MGA modules played various roles in the four fields—Fun Math Camps, MGA teacher training workshops, MGA instructor training workshops, and MGA module designer workshops (see the Appendix for an example of the MGA modules). The modules were the materials for teachers to learn from, and their final products, in the MGA module designer workshops. They learned through evaluation and imitation, after which they were expected to design their modules through discussion with teacher educators. Fun Math Camp activities were arranged by MGA teachers according to the MGA modules produced in the designer workshops. MGA teachers experienced professional development in the MGA teacher training workshops, in which the MGA modules constituted the learning materials. They learned how to use MGA modules by engaging in the gamified activities within the modules, after which they discussed how to adapt the modules for their class use with their peers and the MGA instructors. The MGA modules were also learning materials in the MGA instructor training workshops. MGA instructor trainees learned how to train MGA teachers by discussing the pros and cons of the modules, how to modify them, and how they connected to the core ideas of the program. These tasks increased the depth of the trainees' understanding of the modules, thereby equipping them with the competence needed for training MGA teachers.

To ensure the quality and understanding of the practice in all four fields under the program umbrella, the participants were instructed to submit various types of reports. After the Fun Math Camps, the students and MGA teachers were requested to submit reflective reports on their learning and teaching experiences, respectively. After the teacher professional development workshops, the MGA teachers, instructors, and designers were also requested to submit reflective reports on their experiences. Furthermore, expert teachers or teacher educators with extensive experience in the JDM program worked as inspectors, visiting randomly selected math camps and then submitting observation reports. All the data were used as resources for reflection and future modification of the JDM program. Figure 2 presents the relationships between the personnel, instruments, and activities involved in the program (Zaslavsky et al., 2003).

3.2 Document analysis

The documents collected comprised annual proposals and reports of the program, manuals on principles of conduct and evaluative criteria, the forms of reflective reports of all personnel at different levels, the forms of observation reports of the inspectors. We analyzed these documents to delineate the aims, designs, principles of conduct, implementation situations, and outcomes with regard to the essential implementation components in the conceptual framework, thus allowing for the interpretation of the factors that support scaling up implementation. For example, the analysis on the program proposals indicated that the expected products included the MGA modules and revealed the components that they should include, as well as the procedural steps for assuring the number and quality of the modules. The results further directed the authors of the present study to investigate the manuals on principles for module evaluation. In short, the analyses unveiled the information regarding what JDM produced as the source, and the features connected to this source.

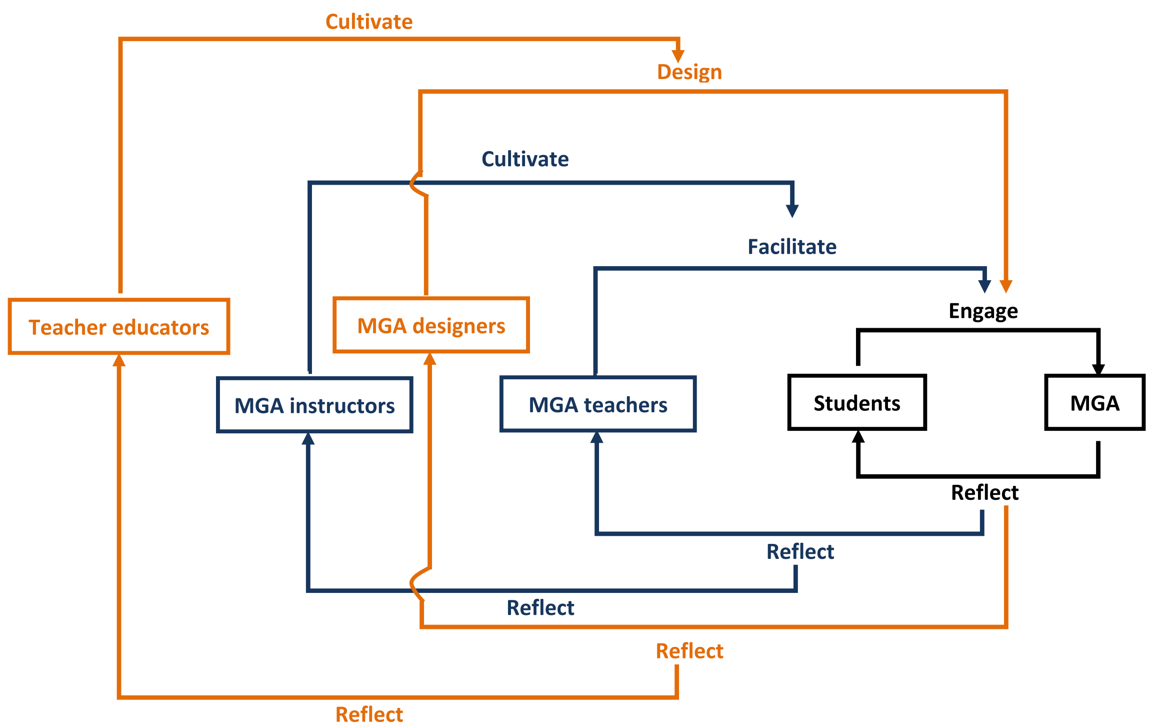


Fig. 2 Relationships between the personnel, instruments, and activities involved in the JDM program (color figure online)

Table 1 Dimensions and sample items of the student reflective report questionnaire

Dimension and sample items	Number of questions
Feelings on the camp e.g., I found the Fun Math Camp interesting; I enjoyed thinking in the Fun-Math Camps	4
Changes and expectations e.g., Participating in the Fun Math Camp made me like mathematics more than before; participating in the Fun Math Camp helped my understanding of mathematics	7
Self-concept e.g., I could understand all the content in the Fun Math Camps; I did well when learning mathematics in Fun-Math Camps	3

3.3 Data analysis

Students' reflective reports after attending Fun-Math Camps were collected and analyzed to understand a feedback mechanism of the JDM program with respect to the essential implementation components in the conceptual framework. MGA teachers are required to analyze their own students' reflections as feedback, in order to facilitate reflection on their own instruction in Fun-Math Camps for the purpose of identifying areas in which to improve. Thus, these student reports constitute a feedback mechanism of the program.

The reflective reports of students were collected using a questionnaire comprising 14 items in three dimensions—feelings on the camp, changes and expectations, and self-concept. The three dimensions were extracted using exploratory factor analysis on student data before 2016 (Lin et al., 2018). Items were scores on a 4-point Likert scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *agree*, 4 = *strongly agree*). The dimensions and sample items are presented in Table 1. The data were collected from 3981 students who had participated in Fun Math Camps in 2019.

The reflective reports of the MGA teachers and MGA designers after the teacher professional development workshops were collected and analyzed to examine the changes initiated by the JDM program with respect to the essential implementation outcomes in the conceptual framework. The reflective reports of the MGA teachers and designers were collected using two questionnaires that had the same dimensions

Table 2 Dimensions and sample items of the teacher reflective report questionnaire

Dimension	Number of questions
Learning in workshops e.g., The workshop helped participants increase their mathematics knowledge; the workshop helped participants learn various teaching methods	3
Beliefs concerning the functions of MGA modules e.g., The MGA modules improved students' mathematical understanding; the MGA modules helped students develop active learning skills	3
Beliefs concerning favorable student learning approaches e.g., The workshop made the participants pay more attention to student engagement in mathematics class than before; the workshop strengthened participants' belief that mathematics learning attitudes and cognition should be developed simultaneously	3
Future teaching practice e.g., The workshop enabled me to provide more opportunities for students to operate teaching aids in mathematics class than before; the workshop enabled me to provide more opportunities for students to engage in discussion in mathematics class than before	4

but featured slightly different items. The dimensions and sample items are presented in Table 2. The dimension of learning in workshops is pertinent to the changes in practitioners' professional behaviors, the dimensions of beliefs concerning the functions of MGA modules and beliefs concerning favorable student learning approaches are related to the changes in organizational culture, and the dimension of future teaching practice is related to the changes in relationships among practitioners. The questionnaire consisted of 13 items that were scored on a 5-point Likert scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *neutral*, 4 = *agree*, 5 = *strongly agree*). The data used in the present study were collected from 924 MGA teachers and 87 MGA designers who participated in teacher training workshops.

To determine whether the evaluations were positive, the students' and teachers' responses were transformed and aggregated. For the students' data, the evaluative scores 1 (strongly disagree) and 2 (disagree) were transformed as *disagree* with score 0 and scores 3 (agree) and 4 (strongly agree) were transformed as *agree* with score 1 for each item. The percentages of agreement and disagreement were calculated. For each item, using a Chi-Square test (Lin, 2007), the percentages of students' agreement and disagreement were compared by testing the null hypothesis that the percentages of all categories would be equal. Furthermore, for each dimension, the average percentage of agreement and that of disagreement were calculated. Similar processes were conducted using the teachers' data, and the only differences were transforming scores 1 (strongly disagree), 2 (disagree), and 3(neutral) to *disagree or neutral* and transforming scores 4 (agree) and 5 (strongly agree) to *agree*.

4 Results

In this section, we elaborate on the design, execution, and evaluation of the JDM program as well as the changes produced according to the essential components and outcomes for successful implementation. We then interpret our findings according to the factors supporting scale-up of implementation, in order to discern what made the JDM program a case of successful scaling up implementation with the purpose of improving student affective performance in mathematics learning.

4.1 Factors in essential implementation components supporting JDM's successful scaling up implementation

4.1.1 Sources

The source in the JDM program included the modules and the videos. The modules included introductions to MGAs (e.g., aims, connections to the curriculum, and activities; see Appendix), worksheets, and explanations of how to conduct MGAs. The modules generated in the MGA module designer workshops were required to undergo a review process documented in the conduct manual of MGA designer workshops. The quality of the modules was assessed by the university-level teacher educators using the following four criteria, as documented in the evaluative forms of modules: (1) the selected mathematical content should be crucial and appropriate; (2) the designed activities should correspond to students' cognitive transformation with regard to mathematical objects; (3) the gamified activities should be interesting and of an appropriate difficulty level; and (4) students should be able to develop concrete mental objects through the activities for use in future learning. The videos were 10-min documentaries of the Fun Math Camps. The designers of the modules (evaluated for their exemplification of the three core ideas of JDM) demonstrated how to lead classes using their modules in Fun Math Camps.[1]

Planning lessons embedding the three core ideas of JDM was challenging because the task differed from regular lesson preparation (Furner & Worrell, 2017). The modules facilitated the arrangement of student activities in the form of the accompanying worksheets and activity introductions as well as the provision of instructive guidance. The modules enabled teachers to implement instruction directly and easily according to the modules, reflecting the characteristic of *low complexity*.

Regarding *the role of adaptation*, the JDM program entailed a highly centralized, diffusive, top-down approach with regard to the packaged, ready-to-go MGA modules and the demonstration videos. Through *a low degree of adaptation*, the program ensured that Fun-Math Camps participants received the learning experience necessary for enhancing their affective performance in mathematics learning, reflecting fidelity when scaling up.

4.1.2 Destination

The JDM program destination is the students who are expected to improve their affective performance toward mathematics learning through the experience in Fun-Math Camps.

Both the MGA modules and MGA teachers were critical components for the success of holding Fun-Math Camps for JDM's destination, the students. The understanding of *adopter characteristics* facilitated the enrollment of MGA designers and teachers. In Taiwan, mathematics classes are fast paced and examination oriented; time-consuming activities are avoided. Learning through the operation of manipulative representations in gamified activities designed to change affective performance in mathematics learning does not directly facilitate achievement of the goal of obtaining high grades on examinations. Thus, its promotion is challenging. The document analysis of the program proposals revealed that the JDM program took adopter characteristics into account through two approaches. First, the core ideas not only included the elements that helped enhance affective performance (C2 and C3) but also the element directly related to academic learning outcomes (C1). Second, the promotion of the three core ideas began outside regular classes in the form of Fun Math Camps held on weekends and during summer and winter vacations, easing the pressure placed on teachers to cover required content in a timely manner and prepare students for examinations.

4.1.3 Communication links

Regarding the communication links in JDM, implementation drivers for ensuring that participating teachers had the necessary knowledge and competence included the MGA designer workshops, MGA instructor training workshops, and MGA teacher training workshops.

The document analysis of program proposals and reports revealed how these workshops were designed and conducted. In evaluating previous modules, the MGA designer workshop participants frequently engaged in discussion with the teacher educators (i.e., the workshop leaders) to understand the essence of the core ideas of JDM and how modules could be designed to reflect them. Under the program, MGA teacher training followed a transformative cascading model. MGA instructor training workshops were held to train MGA instructors who were in turn responsible for training MGA teachers. The MGA instructor trainees discussed the strengths and weaknesses of the modules, how to modify them, and how they connected to the core ideas of the program. These activities increased the depth of the trainees' understanding of the modules, thereby equipping them with the necessary competences for training MGA teachers. The participants in the MGA teacher training workshops learned to use the modules by engaging in the gamified activities and then discussing how to adapt them for class use with their peers and MGA instructors.

The MGA designers, instructors, and teachers acted as intermediates—interpersonal channels between the JDM program and the targeted students. The frequent discussions among teacher educators and designers in MGA module designer workshops, the in-depth and detailed discussions in MGA instructor training workshops, and the practical discussions among MGA teachers and instructors, ensured fidelity of the *communication channels* for sustaining the three cores of JDM in every activity.

The 'cascading' aspect of the program refers to having MGA instructors train MGA teachers, which thereby expands the scope of implementation. However, the MGA teachers did not simply mimic the instructors' example behavior; they attempted the activities themselves in order better to predict their own students' learning situations. Subsequently, they discussed adaptations for their classes with their peers. The MGA instructors were able to provide feasible solutions to the MGA teachers because they

[1] The videos are available at https://cutt.ly/fjSgCVn.

Table 3 Students' evaluations of their experiences at the Fun Math Camps

Dimension	Question percentage of agreement			Average percentage of agreement
	Percentage	χ^2	p value	
Feelings on the camp	86–94	2067.611–3078.875	0.00–0.00	91
Changes and expectations	71–93	696.364–2902.085	0.00–0.00	86
Self-concept	87–89	2128.876–2396.865	0.00–0.00	88

themselves were expert teachers with extensive experience, meaning that they also understood the potential difficulties in implementation. This aspect reflected the features of 'transformation' and flexibility with regard to *a low degree of adaptation*.

4.1.4 Feedback mechanism

The feedback mechanism in JDM that ensured that students would have the necessary experiences to enhance their affective performance in mathematics learning was two pronged, involving both the students' and inspectors' perspectives with respect to the Fun Math Camps. As mentioned, after Fun-Math Camps, the students were required to submit reflective reports as responses to a questionnaire (Table 1). The MGA teachers were also required to submit a reflective report on the instruction provided. One question asked the teachers to record and analyze the students' reflections. The inspectors' observation reports, which included their analysis of and recommendations for the MGA teachers' instruction and the students' learning situations, were also provided for the MGA teachers' reference.

Allowing participating teachers to understand the *relative advantage* of the program over current alternatives to improving affective performance in mathematics learning, was a critical component of the feedback mechanism. Students' opinions, as expressed in their reflections, encouraged or discouraged future implementations by the MGA teachers. Table 3 presents the students' positive evaluations in the three dimensions and the items in each dimension with the information provided by the Chi-Square tests. Regarding feelings on the Fun Math Camps, the students found the camps interesting, the mathematics experienced in the camps was plentiful, and they enjoyed thinking during the process. Regarding changes and expectations, they believed that the camps helped them better understand mathematics, like mathematics more than ever, and successfully learn mathematics in a regular class. They hoped to learn more concepts and perform more exercises in the camps. Furthermore, they wished that they could learn every mathematics topic covered at school at the camps and that regular mathematics classes could follow a similar process. Regarding self-concept, the students did not consider the camp activities difficult; they comprehended all the concepts and performed well overall. According to the results shown in Table 3, we believe that the program could convince the MGA teachers of the relative advantage of using MGA modules over current alternatives to improve affective performance in mathematics learning.

4.1.5 Influence

JDM considered the influence of historical, social, political, and economic factors on the implementation. Regarding the historical factor, the principles of traditional Confucian education, which highly values academic achievement, were taken into account (Leung, 2006). The program proposal revealed that innovation initiation began outside schools, at the Fun Math Camps held on weekends and during summer and winter vacations. Regarding the social factor, previous experience of the failed promotion of innovative mathematics teaching and learning practice in Taiwan led to the consideration of parental acceptance, which in Chinese culture substantially affects both teacher instruction and student learning (Leung, 2006; Lin et al., 2018). The acceptance of JDM in the student community was grounded on the opinions and evaluations of students who had attended at least one of the camps. These students told their peers of their achievements and positive experiences, encouraging them to participate and convince their parents that it would be worthwhile. Furthermore, introductions to MGA modules on various mathematics topics were provided through 10-min live-action videos and 3-min animation videos.[2] These videos allowed parents to understand how JDM would motivate and aid their children in mathematics learning. Taken together, these stimulated the growth of the JDM student community. Regarding the political factor, compulsory education advisory groups operated by Taiwan's national and regional governments were involved in the program. The teachers in these groups were responsible for guiding other teachers in mathematics instruction. With the assistance of the Ministry of Education, they also promoted the program as documented in the program proposals and reports. Regarding the economic factor, with the support of the Ministry of Education, funding was obtained in the form of teaching

[2] Please see https://cutt.ly/RjSgNcl for the 3-min animation videos.

Table 4 Teachers' evaluations regarding changes in professional behavior

Learning in workshops	Question percentage of agreement			Average percentage of agreement
	Percentage	χ^2	*p* value	
MGA teachers	93–99	685.732–880.524	0.00–0.00	95
MGA designers	93–95	64.655–71.736	0.00–0.00	94

Table 5 Teachers' evaluations regarding changes in organizational culture

	Question percentage of agreement			Average percentage of agreement
	Percentage	χ^2	*p* value	
Beliefs concerning the functions of MGA modules				
MGA teachers	87–93	497.494–696.108	0.00–0.00	90
MGA designers	93–99	64.655–83.046	0.00–0.00	96
Beliefs concerning favorable student learning approaches				
MGA teachers	91–98	625.108–841.909	0.00–0.00	95
MGA designers	92–99	61.253–83.046	0.00–0.00	96

subsidies for the Fun Math Camps as documented in the program proposals and reports. The funding also enabled the convening of conferences for MGA teachers from various schools to share their experience of having Fun Math Camps.

High trialability constitutes one factor that supports the scaling up implementation of JDM with regard to the consideration of the historical factor in piloting the innovations outside schools at low cost. *Compatibility* with existing values corresponded to the JDM's consideration of the social factor. JDM's implementation also coincided with *a shift in reform ownership* according to the consideration of the political factor. JDM's conferences for MGA teachers' experience sharing in each year reflected the *observability* of the benefits of the innovations.

4.2 Factors in essential implementation outcomes supporting JDM's successful scaled-up implementation

4.2.1 Changes in practitioners' professional behaviors

In the present study we examined teachers' evaluations of their learning in the professional development workshops (Table 2) to evaluate the changes in practitioners' professional behaviors. As shown in Table 4, the percentage of agreement is significantly higher than that of disagreement from the Chi-Square test for each item, indicating that both the MGA teachers and designers provided positive evaluations with respect to mathematics knowledge acquisition, understanding of student learning in mathematics, and various teaching methods. Regarding the factors supporting JDM's successful scaling up implementation, the percentages reflected the *depth* of the participants' learning.

4.2.2 Changes in organizational culture

To evaluate changes in organizational culture with regard to the support for teachers' implementation of JDM, in the present study we examined participating teachers' beliefs concerning the MGA module functions and favorable student learning approaches (Table 2). As shown in Table 5, the percentage of agreement is significantly higher than that of disagreement from the Chi-Square test for each item. The participants believed that the MGA modules could enhance students' mathematical understanding, improve their attitudes toward mathematics learning, and facilitate the development of active learning skills. Furthermore, they believed that students could learn mathematics well, that teachers should emphasize student mathematical engagement, and that students' learning attitudes and cognitive development should be cultivated simultaneously. As for the factors supporting the successful scaling up implementation of the program, the percentages indicated that both the MGA teachers and designers acknowledged the *relative advantage* of JDM, reflecting the success of the program in the *spread of norms, principles, and beliefs*.

4.2.3 Changes in relationships among practitioners

To evaluate the changes in relationships among practitioners, in the present study we examined the participating teachers' evaluations with regard to conducting learning activities corresponding with those promoted by JDM in their future teaching practice (Table 2). As shown in Table 6, the

Table 6 Teachers' evaluations on changes in relationships among practitioners

Future teaching practice	Question percentage of agreement			Average percentage of agreement
	Percentage	χ^2	*p* value	
MGA teachers	92–95	661.823–738.394	0.00–0.00	93
MGA designers	90–98	54.724–79.184	0.00–0.00	95

percentage of agreement significantly exceeds that of disagreement from the Chi-Square test for each item, indicating that both the MGA teachers and designers believed that the workshops enabled them to provide more opportunities for students to operate teaching aids, engage in discussion, and raise questions in class. They intended to link the module content to the content they covered in regular classes. These results reflect a shift in teacher-student relationships, from lecturer-knowledge receiver to facilitator-knowledge builder. As for the factors supporting the successful scaling up implementation of the program, the percentages reflected the *sustainability* potential for the implementation of JDM in regular mathematics classes by the MGA teachers and designers.

5 Discussion and conclusion

Students' negative affective performance in mathematics learning is a worldwide problem to which substantial mitigation efforts have been devoted. The well-known theory of teaching and learning developed in the Freudenthal Institute, Realistic Mathematics Education (RME), proposes an approach to enhancing mathematics learning motivation centered on providing students with opportunities to explore and discover mathematics (Fauzan et al., 2002; Van den Heuvel-Panhuizen & Drijvers, 2014). JDM is in line with this idea but takes a different approach with regard to the cognitive factor of learning motivation. In terms of sense-making, RME uses realistic problems as a meaningful source of learning, whereas JDM uses gamified activities requiring students' engagement with concrete representations. In terms of the value of mathematics learning through inquiry, in RME students are expected to solve real, possibly complex, problems using mathematical concepts or regularities they abstracted, whereas JDM promotes the development of fundamental prerequisite mathematical ideas that facilitate understanding of the content covered in regular class (Karaca & Özkaya, 2017). It is acknowledged that feasible approaches can vary depending on context or culture. The scope of the program demonstrates its higher-than-average impact on mathematics education with regard to improving students' affective performance; thus, the approaches in JDM can enrich our understanding in promoting mathematics learning motivation.

Concerning the implementation of innovative teaching methods, some researchers have advocated top-down approaches involving the dissemination of ideas from researchers or teacher educators to teachers, whereas others have supported regarding teachers as inquiry-based learners (Krainer & Zehetmeier, 2013; Maass et al., 2019). Given that Taiwan is among the examination-oriented, high-achieving countries of East Asia, it is possible that mathematics teachers may not be willing or able to implement the innovative instructional methods promoted by JDM. Thus, a top-down approach was employed, with the consideration of essentials for successful implementation, namely sources and communication links, to foster adoption of the innovation. Moreover, the premise that any innovative teaching approach should be adaptable to local classroom contexts was taken into account (Weatherley & Lipsky, 1977). Thus, the teachers were given the authority to adapt the MGA modules for class use, opportunities to discuss their adaptation in the professional development workshops, and to inquire and reflect on their own practice of adaptation in the Fun Math Camps (Zaslavsky et al., 2003), reflecting the bottom-up features. Specifically, the program approaches fell between top-down and bottom-up (more the former and less the latter), with participating teachers regarded as both adopters and adapters.

Education research on implementation aims to resolve problems encountered in practice, whereas that on scaling up aims to uncover the factors contributing to the expansion of the scope of situations in which innovative educational ideas or approaches are employed. It is beyond the scope of this study to answer comprehensively what drives the success of scaling up implementation. Nevertheless, this study proposed a framework through synthesizing the literature determining the essentials of successful implementation, and that of the factors relevant to successful scale-up. The framework emphasizes the structure of the elements that support successful implementation, addressing their implications with regard to factors that promote scaling up. Furthermore, the case of JDM provides a picture and connotations of the factors that contribute to successful scaling up implementation; the findings of the present study further the knowledge on general education literature as it pertains to mathematics education practice.

In terms of essential components for successful scaling up implementation, the JDM program included the packaged ready-to-go MGA modules and the demonstration videos with regard to the source component. The sources reflected the low complexity characteristic with respect to ease of use by teachers as well as a low degree of adaptation for fidelity. The *destination* of JDM is students to be helped for enhancing affective performance in mathematics learning. Regarding this component, adopter characteristics were taken into account through addressing teachers' concerns regarding time-consuming activities. The innovative activities were initiated outside schools. For the communication link component, the MGA module designer, instructor training, and teacher training workshops were the implementation drivers. In those workshops, in-depth discussions were conducted to ensure the fidelity of the communication channels for sustaining the three core ideas of JDM in each activity. Regarding the feedback mechanism component, the requirement of MGA teachers to analyze students' feedback helped them understand the relative advantage of the JDM innovation over other current alternatives with respect to improving affective performance. For the influence component, historical, social, political, and economic factors were considered. Program implementation reflected high trialability, compatibility, a shift in reform ownership, and observability, the characteristics contributing to successful scaling up.

In terms of essential outcomes for successful scaling up implementation, in this study we assessed the changes in practitioners' professional behaviors by examining the MGA designers' and teachers' evaluations. The positive evaluations reflected the depth of teachers' learning through the program. To evaluate the changes in organizational culture in the support of JDM implementation, in this study we examined MGA designers' and teachers' beliefs regarding module functions and favorable mathematics learning approaches. The teachers acknowledged the relative advantage of the implementation of JDM and the success of the spread of norms, principles, and beliefs. To investigate the changes in relationships among practitioners, in this study we examined the MGA designers' and teachers' evaluations concerning the shift in teacher–student relationships from lecturer-knowledge receiver to facilitator-knowledge builder. The positive evaluation indicated the sustainability of JDM implementation in and adaptation to regular mathematics classes.

Given the multidimensionality and complexity of the framework for exploring factors contributing to successful scaling up implementation, research on the relationships and possible tradeoffs among relevant factors is warranted. The use of teachers' self-evaluations as evidence of essential outcomes regarding changes in practitioners' professional behaviors may have been a limitation. Specifically, the workshop participants may have had positive expectations of the innovations promoted by the program. To enhance validity, external evaluations of changes in participating teachers can be conducted alongside internal self-evaluation in future studies.

Appendix

Just Do Math–Not Only Rats Can Punch Holes

1. Activity Materials

   (1) Operation sheets (one piece per group).
   (2) Worksheets (one piece per group).
   (3) Reflection notes (one piece per student).
   (4) Hole punchers (one piece per group).
   (5) Colored paper (several pieces per group).

2. Activity description
   (1) Topic description

   I. This activity aims to introduce the concept of line symmetry through the actual act of punching holes in origami. By using levels that range from easy to difficult, students can explore the mystery of line symmetry in figures.
   II. The activity should precede the unit on "vertical, bisected, and line-symmetric figures" corresponding to the new curriculum "S-7-4: Properties of Line Symmetry."
   III. The activity is suitable for first-year students in junior high school.

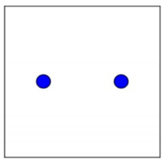
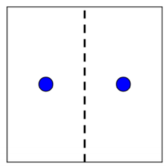
(2) Activity objectives and core concepts

   I. Activity objectives: Through the hands-on activities, to think about and explore the relationship between point of symmetry, axis of symmetry, and line-symmetric figures.
   II. Core concepts: Observe the components of line-symmetric figures to facilitate comprehension in subsequent lessons.

3. Activity process
(1) The activity is conducted in pairs.
(2) The first rule of activity:
   Fold the colored paper in half twice and then cut it into four small squares along the lines. Punch a hole in the paper and then glue it to the operation sheets. (Note: Do not crease the colored paper too much).
(3) The second rule of activity:
   Please follow the explanatory figures given in each level. Fold the paper and then make a hole in it with the hole puncher. (Note: Punch only one hole). Next,

unfold the paper. If it looks the same as the paper in the provided picture, you have passed this level.

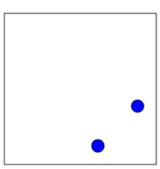
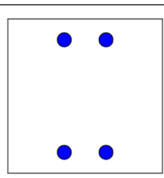
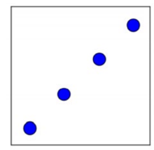
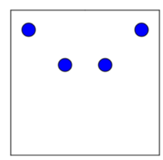
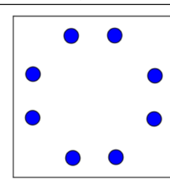
(4) Examples

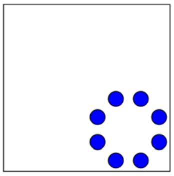
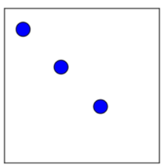
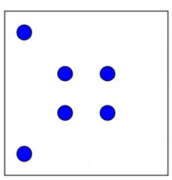
The challenge is shown in the picture below (with two holes).	Glue your colored paper here.
	
At least how many times do we need to fold?	Answer: ___1____time(s).

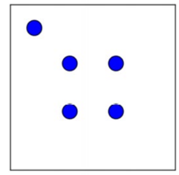
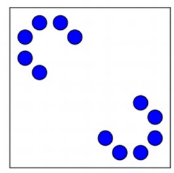
(5) Scoring method

* Level 1 to 4 (basic): 12 points per level.
* Level 5 to 6 (advanced): 10 points per level.
* Level 7 to 10 (expert): 8 points per level.
* The group with the highest scores at the end of the activity wins.

4. Operation sheets (one piece per group).

Level 1 is shown in the picture below (with two holes).	Glue your colored paper here.
	
At least how many times do we need to fold? Answer: _______time(s).	
Level 2 is shown in the picture below (with four holes).	Glue your colored paper here.
	
At least how many times do we need to fold? Answer: _______time(s).	
Level 3 is shown in the picture below (with four holes).	Glue your colored paper here.
	
At least how many times do we need to fold? Answer: _______time(s).	
Level 4 is shown in the picture below (with four holes).	Glue your colored paper here.
	
At least how many times do we need to fold? Answer: _______time(s).	
Level 5 is shown in the picture below (with eight holes).	Glue your colored paper here.
	
At least how many times do we need to fold? Answer: _______time(s).	
Level 6 is shown in the picture below (with eight holes).	Glue your colored paper here.

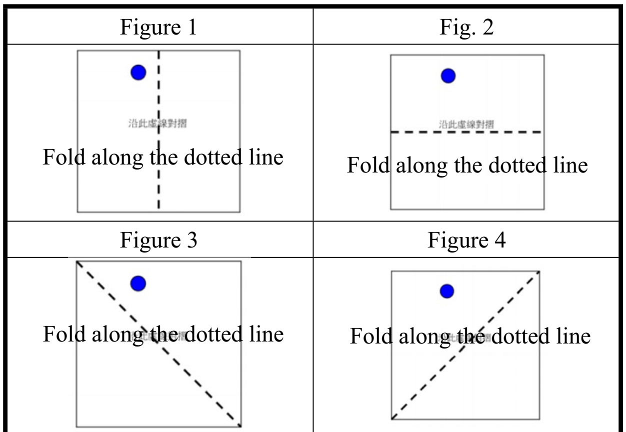
	
At least how many times do we need to fold? Answer: _______time(s).	
Level 7 is shown in the picture below (with three holes).	Glue your colored paper here.
	
At least how many times do we need to fold? Answer: _______time(s).	
Level 8 is shown in the picture below (with six holes).	Glue your colored paper here.
	
At least how many times do we need to fold? Answer: _______time(s).	
Level 9 is shown in the picture below (with five holes).	Glue your colored paper here.

	
At least how many times do we need to fold? Answer: _______time(s).	
Level 10 is shown in the picture below (with twelve holes).	Glue your colored paper here.
	
At least how many times do we need to fold? Answer: _______time(s).	

5. Worksheets (one piece per group).

◎ **Let's draw!** (Part 1)

After finishing the game, let's try to draw the figures! Think carefully! Follow the instructions for all four pictures below and then punch holes according to the existing holes in the picture. After you unfold the paper, where will the other hole be? (Discuss with your partner and then draw your answer in the figures below).

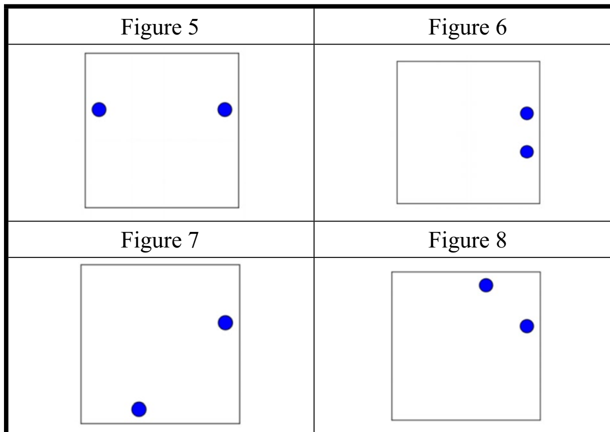


※ As we learned in elementary school, if a figure can be folded in half along a straight line to produce two completely overlapping figures on both sides of the straight line, it is called a line-symmetric figure.

Q1: Discuss in groups this question: "What is the role of the dotted line in the line-symmetric graph?"
Answer: ____

Q2: In fact, the original holes in Figures 1–4 are the same. But, according to the instructions, are the punched holes in the same place?
Answer: ____

Q3: Discuss in groups this question: "What is the connection between two holes on the same piece of colored paper? (If you regard two holes as two points, what is the role of these points in the line-symmetric graph?")
Answer: ____



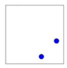
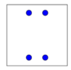
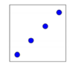
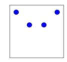
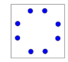
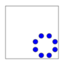
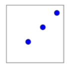
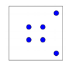
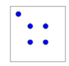
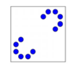
Q4: How do you find the folding line?
Answer: ____

Q5: Connect the two holes in Figures 5–8 with a ruler and draw a line segment. Find the connection between the segment and the folding line. (Try to answer the question in mathematical terms).
Answer: ____
____
____

◎ **Let's draw!** (Part 2)

The following are the pictures after the hole punching. Where will the folding lines of each graph be? Discuss in groups and then draw your answer on the figures!

6. Reflection notes (one piece per student).

Topic	**Not Only Rats Can Punch Holes.**		**Name: ___________**	
Concepts that I learned:				
Level 1	Level 2	Level 3	Level 4	Level 5
				
Level 6	Level 7	Level 8	Level 9	Level 10
				
Please answer the following questions:				
Q1: Examine the basic levels (1–4) and the advanced levels (5–6). What is the connection between the number of holes and the number of times you fold the paper? Answer: ____ Q2: If you are asked to punch the holes precisely (compare the difference between levels 5 and 6), what do you need to pay special attention to? Answer: ____ Q3: How do you hole punch a figure with an odd number of holes (e.g., levels 7 and 9)? Answer: ____ Q4: Draw the axis of symmetry in the above figures (draw directly on the figures). Do you think the axis of symmetry is the same line as the folding line? What kind of role does the folding line play in this game? Answer: ____ ____				
Please write down your other findings here:				
My opinions on this way of learning:				
Self-evaluation and other evaluations:				
I give myself _______ star(s) (up to 5) because____				
My partner is ___________. I give him/her______ star(s) (up to 5) because:___________________________				

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