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Author(s)	Tan Li Li and Lucille Lee Kam Wah
Source	*ERA Conference, Singapore, 23-25 November 1998*
Organised by	Educational Research Association of Singapore (ERAS)

Teachers' Use of Problem-solving Teaching Approach in Teaching Primary Science

Tan Li Li
Pasir Ris Primary School
&
Dr Lucille Lee Kam Wah
National Institute of Education, Nanyang Technological University

Introduction

One of the important aims of science education is to improve students' abilities to think critically, reason logically and ultimately to solve problems (Lavoie, 1993). Many government authorities and educators such as the United Kingdom, United States of America, Japan and Singapore are assessing the strengths and weaknesses of their education systems and reforming them to better prepare their societies for the demands of the future.

Science is a subject that lends itself well to problem solving due to its wide range of problem types that occur within its domain (Adey, 1997). Science teachers are in a suitable position to promote the development of thinking skills in students (Lee, 1997). Problem solving can be considered as a complex learning activity that involves thinking (Garett, 1986).

Definitions

- **Problem**

In this study, the term "problem" refers to a science investigative task that is conducted in the primary school science classrooms. The science investigative task requires the use of skills, knowledge and science procedures. The science investigation involves the pupils to come up with suitable answers or decide which is the best solution to a problem. The problem in the investigation could originate from the teacher or the pupils.

- **Problem-solving teaching approach**

Another term "problem-solving teaching approach" which is used in the study refers to the use of teaching strategies that fosters problem-solving skills. The problem-solving teaching approach requires the pupils to ask relevant questions, explore, formulate hypotheses, plan investigations, predict outcomes, experiment, collect and evaluate data, draw conclusions, express their ideas, evaluate the ideas of others and seek alternative explanations.

Problem-solving skills

Science teaching in Singapore primary schools is guided by a national primary science curriculum, the *Primary Science Syllabus* (1990). Among the aims of the syllabus is to "develop in pupils positive attitudes which are characterized by being curious, persistent, caring and capable of thinking critically and creatively (*Primary Science Syllabus*, 1994, page 7). Thinking skills are categorized into eight main types, namely, focusing, information gathering, remembering, integrating, organizing, analyzing, generating and evaluating (*Primary Science Source Book*, 1997, page 1). Science education advocates the development of science process skills. There are two sets of skills – basic process skills and integrated process skills (Gagné, 1965). The science process skills identified in the *Primary Science Syllabus* are similar to the ones proposed by Gagné (1965). The problem-solving skills referred to, in the study, are integrated process skills.

Background of the study

Local studies on problem solving at the primary level appear to be lacking though there are studies on problem solving in other subjects, for example in Mathematics (Sitsofe, 1996; Fong, 1997) and in chemistry (Boo, 1995; Lee, Goh, Chia and Chin, 1996). However, most of these studies involved secondary and junior college pupils.

Science teachers in Singapore primary schools are expected to use a variety of approaches to teach science to cater to different learning styles of children. One teaching approach in science is the problem-solving teaching approach (Chin, Goh, Chia, Lee and Soh, 1994).

From the first author's personal teaching experience and her interaction with fellow teachers, it was found that teaching primary school science using the problem-solving teaching approach posed a challenge to many teachers. This observation is supported by Chin et al.'s study (1994) that the pre-service teachers encountered difficulties in using the problem-solving teaching approach to teach science.

Would trained science teachers in primary schools also face the same difficulties? What would be their views on the problem-solving teaching approach in teaching and learning science? To what extent is the problem-solving teaching approach used in primary schools? More fundamentally, what do the teachers know about their roles of being science teachers? It is important to know what is the situation in schools where teaching problem solving is concerned, before we can improve the teaching methods of developing thinking skills through problem solving.

This paper reports a part of the results of the study concerning the teaching of problem solving in primary schools (Tan, 1997). It is focused on the primary school teachers' views about (1) their roles as science teachers and (2) their use of the problem-solving teaching approach in particular. Two of the research questions in the study are shown below:

1. What are the personal beliefs concerning the role of a primary school science teacher?
2. To what extent are problem-solving activities carried out in a primary school science classroom?

Sample

The sample comprised 348 trained teachers from 36 primary schools in Singapore. The schools were selected at random out of a total of 192 primary schools in Singapore (Education Statistics Digest, 1996). The sample comprised 64 (18.4%) male teachers and 284 (81.6%) female teachers. The 36 (i.e. 30 Government schools and 6 Government-aided schools) schools in the sample formed 18.8% of the total number of primary schools in 1996.

The teachers had taught primary school science for at least three years. Three years of teaching experience were believed to be long enough for a science teacher in a primary school to gain experience and confidence in teaching the subject. The *Primary Science Syllabus* was reviewed and was first implemented in primary schools in 1990. As such, the study focused on teachers who had taught science using the Primary Science Syllabus from 1991 to 1996.

The average age of the sample is 38 years. The average number of years of teaching is about 20 years. About 40% of the teachers had obtained Advanced level and 38% had Ordinary Level qualifications. About 75% of the teachers indicated that they had taken science courses in their educational qualifications.

Generally across the four types of educational levels, from Ordinary Level to University, Biology was the subject teachers most commonly studied. This was the case for teachers whose highest qualification were Ordinary Level, Advanced Level and Diploma Level. For teachers whose highest qualification was Advanced Level, Biology and Combined Science were commonly taken.

Instrument

The study used a survey method. A questionnaire, namely, "Use of Science Instructional Techniques" was used to find out answers to the four areas of investigation. The questionnaire was adapted from a previous study by Chin et al. (1994). The nine-paged questionnaire contained items in three categories, namely, teachers' characteristics, activities in the classroom and factors influencing teachers' use of problem-solving teaching approach. There were 78 scaled items and 14 open-ended items. The scaled items required the teachers to respond to statements on a Likert scale from 1 to 5, and the open-ended items required the teachers to write down their comments in the spaces provided. For each of the scaled items, there was also a space provided for teachers to write their views.

Method

In early 1996, 500 copies of the questionnaire were distributed to various primary schools selected at random, and 348 copies were returned (69.8% response rate). The completed questionnaires were collected by early June 1996. The data was then analyzed.

Given the nature of the questionnaire, the data belonged to two types. In the first type of data, the teachers' views were expressed in the form of scaled data to the statements. This formed the quantitative data. In the second type of data, information was collected in the form of written answers to the open-ended questions, and in the remarks column of each section. This formed the qualitative data. As a result, data analysis was carried out from the quantitative and qualitative perspectives.

Results

Part of the results of the study pertaining to the two research questions is described. In the following paragraphs, the teacher is referred to as a "she" regardless of gender, and the comments from a teacher are identified in terms of her serial number in the sample. For example, the code "tr-7" refers to the seventh teacher in the total sample of 348 teachers.

- **Roles of a science teacher**

The scaled items in Section Two of the questionnaire provided quantitative data on the teachers' views about their roles as science teachers in primary schools. Three factors emerged from the analysis of the data, namely, the role of imparting of science knowledge, providing opportunities to develop skills, and cultivating pupils' interest in science.

In the design of Section Two, the items were divided into two categories, namely, "Teacher's beliefs" and "Teacher's actions". Altogether, there are ten items in this section. The response distribution to the items of Section Two is shown in Table 1. The percentage responses ("strongly agree") to the items concerning the above-mentioned three roles under "Teachers' belief" and "Teachers' actions" are shown in Table 2. The figures in Table 2 were rounded up to the nearest whole numbers.

Table 1: Response distribution (%) to Section Two – Teacher's role in teaching science

ITEM	SD (1)	D (2)	WD (3)	WA (4)	SA (5)	MEAN	STD DEV
#2-1 As a science teacher, I am responsible for imparting science knowledge to my pupils.	2.3	0.6	1.7	24.7	69.5	4.6	0.9
#2-2 As a science teacher, I provide opportunities in the science lessons for the pupils to acquire skills to handle problems.	1.7	0.9	0.6	35.3	60.6	4.5	0.8
#2-3 As a science teacher, I guide the pupils to discover things for themselves.	2.0	0.6	0.9	35.9	59.2	4.5	0.9
#2-4 As a science teacher, I cultivate interest in science among my pupils.	2.3	0.3	0.6	24.1	71.8	4.6	0.9
#2-5 As a science teacher, I help my pupils to develop an enquiring mind about things around them.	2.0	0.9	1.4	26.4	67.8	4.5	0.9
#2-6 As a science teacher, I should provide opportunities for the pupils to develop problem-solving skills.	1.1	1.1	2.3	34.2	60.1	4.5	0.9
#2-7 I always (almost every lesson) impart science knowledge to pupils.	1.7	1.7	7.8	41.4	46.6	4.3	0.9
#2-8 I always (almost every lesson) provide opportunities for pupils to acquire skills.	0.9	2.3	9.8	61.2	24.7	4.0	0.8
#2-9 I always (almost every lesson) provide opportunities for the pupils to discover things for themselves.	0.9	2.0	14.4	59.5	22.1	4.0	0.8
#2-10 I always (almost every lesson) provide opportunities for the pupils to develop problem-solving skills.	0.9	2.3	16.4	60.9	18.7	3.9	0.8

SD = Strongly Disagree D = Disagree WD = Somewhat Disagree
WA = Somewhat Agree SA = Strongly Agree Std Dev = Standard Deviation
Mean scores were based on a scale of 1= Strongly Disagree (SD) to 5 = Strongly Agree (SA)

Table 2:Comparison of the teachers' beliefs and the teachers' actions in their roles of being science teachers

ROLES	TEACHER'S BELIEFS ITEM	SA (%)	TEACHER'S ACTIONS ITEM	SA (%)
Imparting science knowledge	#2-1	70	#2-7	47
Providing opportunities to develop skills				
• Problem-solving skills	#2-2	61	#2-8	25
	#2-6	60	#2-10	19
• Discovery/Inquiry skills	#2-3	59	#2-9	22
	#2-5	68	-	-
Cultivating pupils' interest in science	#2-4	72	-	-

SA = Strongly agree

- **Imparting science knowledge**

From Table 2, in the teacher's belief category, about 70% of the teachers (#2-1) strongly agreed that they were responsible for imparting science knowledge to their pupils but in the teacher's action category, about 47% of the teachers (#2-7) strongly agreed that they did so. An example of the teachers' comments on the role of imparting science knowledge to their pupils is as follows:

 813

- "The imparting of the science knowledge is more to get the pupils to think with scientifically accepted terms and concepts." (tr-93).

More information from the qualitative data about how the teachers viewed their roles of being science teachers is summarized in the following paragraphs.

Some science teachers considered themselves as facilitators in the process of pupils' learning. The following teachers' comments support this finding:

- "The teacher is a facilitator, advisor and a resource person." (tr-93); and
- "The teacher needs to guide pupils to take the necessary steps when the pupils are solving a problem." (tr-330).

Some teachers thought that they encouraged the pupils to seek knowledge for themselves and to promote self-directed learning. They also felt that pupils should be responsible for their own learning:

- "Pupils should also learn to seek science knowledge themselves." (tr-166); and
- "The teacher should encourage pupils to widen their knowledge by finding facts and reading up from references in school and public libraries."(tr-11).

In developing a better understanding of the nature of science, some teachers believed that pupils should be aware that science theories were subject to validation and change. The following are examples of the teachers' comments on this view:

- "The teacher should help pupils realize that scientific theories are as true as man's knowledge of science takes him." (tr-73); and
- "There is also the role of imparting an awareness that a scientific theory is just one way of defining reality and not reality itself. Students should not hold currently accepted theories as the truth and should challenge their validity." (tr-93).

Science concepts are related to daily life. Some teachers considered that they helped to facilitate the pupils in the application of science knowledge to everyday living. Some teachers' comments on the applications of science are as follows:

- "Teachers should point out to pupils that many of the things they learnt in science are actually happening in real life situations so that there is a link in understanding concepts." (tr-23 and -336); and
- "The science teacher has the role of addressing the child's use of layman's concepts of science in scientific situations." (tr-93).

- **Providing opportunities to develop skills**

From Table 2, for the development of problem-solving skills, in the teacher's belief category, about 61% of the teachers (#2-2) strongly agreed that they provided opportunities for pupils to acquire skills to handle problems. About 60% of the teachers (#2-6) strongly agreed that they should provide opportunities for problem solving. There was a disparity between the teachers' beliefs and actions. In the teacher's action category, it was only about 25% of the teachers (#2-8) strongly agreed that they provided opportunities to develop skills to handle problems, and about 19% of the teachers (#2-10) indicated that they provided opportunities for the pupils to develop problem-solving skills.

For the development of discovery/inquiry skills, about 59% of the teachers (#2-3) strongly agreed that they guided the pupils to discover things for themselves, and about 68% of the teachers (#2-5) strongly agreed that they helped their pupils to develop an enquiring mind about things around them. In contrast, in the teacher's action category, it was less than a quarter (about 22%) of the teachers (#2-9) strongly agreed that they always provided opportunities for the pupils to discover things for themselves.

 814

Some qualitative data confirmed that the teachers did appreciate their role to develop skills, such as science basic process skills and higher-order thinking skills (e.g. discovery/inquiry skills and problem-solving skills). Examples of the teachers' comments to support this finding are as follows:

- "Teachers should teach their students the higher-order thinking skills to solve problems and constantly challenge them with problems involving science. In short, teachers must teach the pupils the strategies/skills in solving science related problem so that they can come out with creative/innovative situations; the pupils must be able to solve problems using metacognition." (tr-249); and
- "Students have to be given the opportunity to handle apparatus and to take risk and there should be opportunities for them to develop problem-solving skills as the science syllabus requires that to be incorporated." (tr-93).

- **Cultivating interest in science**

Another important role of the science teachers, based on the data, is to cultivate interest in science among the pupils. From Table 2, about 72% of the teachers (#2-4) strongly agreed that they cultivated the pupils' interest in science. The following teachers' comments support this finding:

- "The role of a science teacher is to make science interesting so as to sustain pupils' interest and arouse their curiosity." (tr-52); and
- "The teacher models but encourages the pupils to be more vocal and feel assured about seeing the same situation from different perspectives and students should reach a stage where their interest remains regardless of external motivator." (tr-93).

Science instructional situation in primary schools

The scaled items in one of the sections of the questionnaire (Section Three A) provided quantitative data on an aspect of the science instructional situation in a primary school, i.e. the type of tasks that pupils carry out in the science classroom.

Table 3 shows the response distribution to Section Three A of the questionnaire. Tables 4 and 5 show the teachers' percentage responses ("often" and "always") under two categories of the items in Section Three A. The two categories are "General hands-on activities" (Table 4) and "Tasks pertaining to problem solving" (Table 5). The figures in Tables 4 and 5 were rounded up to the nearest whole numbers.

Table 3: Response distribution (%) to Section Three A – Pupils' tasks

When engaged in the science activities, the pupils:

ITEM	AN (1)	SE (2)	ST (3)	OF (4)	AL (5)	MEAN	STD DEV
#3A-1 carry out specific activities from the workbook or teacher's worksheet.	0	0.3	4.3	44.0	51.1	4.5	0.6
#3A-2 identify a researchable question or problem themselves.	6.6	19.3	42.5	27.3	3.2	3.0	1.0
#3A-3 list as many questions as possible about a topic in the given opportunity.	5.7	22.4	35.3	28.4	7.2	3.1	1.1
#3A-4 follow detailed instructions to perform the activity or experiment.	0.9	4.3	11.8	46.8	36.2	4.1	0.9

#3A-5	design an experiment with little or no assistance.	14.1	31.3	32.5	19.0	2.3	2.6	1.1
#3A-6	identify appropriate apparatus and resources for their practical activities.	5.2	11.2	32.8	33.6	16.7	3.4	1.1
#3A-7	form hypotheses about the outcomes before carrying out the activities.	5.2	11.5	34.8	37.6	10.6	3.4	1.0
#3A-8	perform experiments to verify previously taught concepts	4.9	14.1	31.6	35.9	12.6	3.4	1.1
#3A-9	perform experiments to demonstrate concepts.	2.0	4.6	21.6	50.6	20.7	3.8	1.0
#3A-10	interpret results of their experiments.	0.6	1.7	14.4	52.3	30.2	4.1	0.8
#3A-11	make a presentation of their question, method, data and conclusion.	7.5	14.4	37.6	29.3	10.6	3.2	1.1
#3A-12	work in small co-operative groups.	0	2.9	15.5	44.5	37.1	4.2	0.8
#3A-13	ask questions for procedural clarification.	2.0	10.1	29.9	37.1	21.0	3.7	1.0

AN = Almost never AL = Always (almost every lesson) SE = Seldom (once in several weeks)
ST = Sometimes (about once in a fortnight) OF = Often (about once a week) Std Dev = Standard Deviation
Mean scores were based on a scale of 1 = Almost Never to 5 = Always

- **General hands-on activities**

The items in the category, "General hands-on activities" were further grouped under two categories, namely, "Prescribed problem/question for investigation", and "Type of activity" (Table 4). About 95% of the teachers (#3A-1) indicated that their pupils either often (about once a week) or always (almost every lesson) carried out specific activities from the science workbooks or from the teacher's worksheets. About 83% of the teachers (#3A-4) said that their pupils either often (about once a week) or always (almost every lesson) followed detailed instructions. The percentage of teachers using science workbooks was high because the science workbooks were prescribed by the Singapore Ministry of Education to be used as part of the primary school science programme. However, some teachers used activities beyond those found in the workbooks by planning their own activities. The evidence is shown in the following teachers' comments:

- "Instead of just following the instructions in the workbook, some of the questions are changed to be more investigative in nature." (tr-319); and
- "The pupils discuss different methods in performing the same experiment." (tr-158).

Table 4: General hands-on activities

DESCRIPTION	ITEM	% (I) OFTEN	% (II) ALWAYS	% (I & II) TOTAL
Prescribed problem/question for investigation				
• Pupils carry out specific activities from the workbook or teacher's worksheets.	#3A-1	44	51	95
• Pupils follow detailed instructions to perform the activity or experiment.	#3A-4	47	36	83
• Pupils ask questions for procedural clarification.	#3A-13	37	21	58
Type of activity				
• Pupils perform experiments to verify previously taught concepts.	#3A-8	36	13	49
• Pupils perform experiments to demonstrate concepts.	#3A-9	51	21	72
• Pupils work in small co-operative groups.	#3A-12	45	37	82
• Pupils interpret the results of experiments.	#3A-10	37	21	82

Often = About once a week Always = Almost every lesson

About 58% of the teachers (#3A-13) indicated that the pupils either often (about once a week) or always (almost every lesson) asked questions for procedural clarification. This is supported by two teachers' comments:

- "The teacher encourages the pupils to ask questions pertaining to the observations they have made." (tr-238); and
- "Pupils need to understand certain concepts about the problem, before being able to solve it. They also need to understand what the aim of the experiment is, what do they want to interpret and what variables must they change or keep constant. They need to ask themselves these questions before attempting the experiment." (tr-269).

For the type of activities conducted in schools, about 49% of the teachers (#3A-8) said that their pupils either often (about once a week) or always (almost every lesson) performed experiments to verify previously taught concepts. About 72% of the teachers (#3A-9) indicated that their pupils either often (about once a week) or always (almost every lesson) performed experiments to demonstrate concepts. About 82% of the teachers (#3A-12) indicated that the pupils either often (about once a week) or always (almost every lesson) carried out group work. And about 82% of the teachers (#3A-10) indicated that the pupils either often (about once a week) or always (almost every lesson) interpreted the results of the experiments.

- **Tasks pertaining to problem solving**

As shown in Table 5, about 30% of the teachers (#3A-2) indicated that the pupils either often (about once a week) or always (almost every lesson) identified researchable problem themselves. Some teachers felt that this task was rather difficult for less able and less motivated pupils. The following teachers' comments reflect this finding:

- "The weak pupils are unable to cope with this task." (tr-37); and
- "Most pupils do not bother unless pressed to do so." (tr-166).

Table 5: Tasks pertaining to problem solving

DESCRIPTION	ITEM	% (I) OFTEN	% (II) ALWAYS	% (I & II) TOTAL
• Pupils identify researchable problems themselves.	#3A-2	27	3	30
• Pupils list as many questions about a topic in the given opportunity.	#3A-3	28	7	35
• Pupils design an experiment with little or no assistance.	#3A-5	19	2	21
• Pupils identify apparatus and resources for their practical activities.	#3A-6	34	17	51
• Pupils form hypothesis about the outcomes before carrying out the activity.	#3A-7	38	11	49
• Pupils interpret results of the experiment. *	#3A-10	29	11	82
• Pupils make presentations of the question, method, data and conclusions.	#3A-11	29	11	40
• Pupils work in small co-operative groups. *	#3A-12	45	37	82
• Pupils ask questions for procedural clarification. *	#3A-13	37	21	58

* The items are also found in Table 4.
Often = About once a week Always = Almost every lesson

About 35% of the teachers provided opportunities for the pupils (#3A-3) to list as many questions about a topic. In this aspect, some teachers expressed their concern about pupils' ability to form even a proper question (tr-211). In addition, only about 21% of the teachers (#3A-5) indicated that the pupils either often (about once a week) or always (almost every lesson) designed an experiment with little or no assistance. Furthermore, about 40% of the teachers (#3A-11) indicated that the pupils either often (about once a week) or always (almost every lesson) made a presentation of the question, method, data and conclusion. Pupil's ability was quoted as a factor affecting these three problem-solving tasks:

- "Weak pupils have difficulty grasping the concepts that are required in a question on problem solving." (tr-320); and
- "The pupils are always at a loss, they need lots of guidance." (tr-336).

About 51% of the teachers (#3A-6) indicated that the pupils either often (about once a week) or always (almost every lesson) identified apparatus and resources for their practical activities. One teacher commented that in some investigations where the required apparatus was not available, the pupils made a list of the equipment needed (tr-166). About 49% of the teachers (#3A-7) indicated that the pupils either often (about once a week) or always (almost every lesson) formed hypotheses about the outcomes before carrying out the activity. Some teachers' views about formulating hypothesis are shown below:

- "Finding an acceptable answer to the problem, perhaps after narrowing it down from several hypotheses. "(tr-266); and
- "Problem solving in learning science involves formulating a hypothesis about a problem." (tr-319).

Two items, #3A-12 (pupils working in small co-operative groups) and #3A-10 (pupils interpret results of experiment), also had high percentage response (82% for both items). Pupils are required to report and interpret results from experiments/exercises in the science workbooks. A number of teachers commented on the advantages of working together in small groups.

Discussion

From the survey, it was found that there were three roles which the teachers believed in. The three roles were namely, (1) to impart science knowledge, (2) to facilitate science learning to develop science skills, such as problem-solving and inquiry skills, and (3) to cultivate interest in science. This finding is supported by literature. From the literature, the roles of the science teachers include the imparting of science knowledge, developing science process skills and cultivating interest in science (Shapiro, 1996; Shepardson, 1997). Many teachers agreed with these roles (Table 2, Teacher's beliefs). The role of a science teacher is pivotal in supporting children's learning in science (Gilbert and Qualter, 1996). The teacher eases from the role of a transmitter of knowledge to the role of a facilitator who encourages pupils to find solutions to worthwhile problems (Gabel, 1995).

However, Germann (1989) found that despite the priority of improving pupils' thinking skills, science teachers in general, place a greater emphasis on the acquisition of content knowledge rather than on the development of procedural skills. Germann's finding is supported by this study that science teachers in primary schools appreciate the importance of problem solving and discovery/inquiry skills in daily living, yet the opportunities for developing such skills, in particular problem-solving skills, are fewer in the science classroom.

Among the various types of pupils' tasks in the science classroom, the most popular "General hands-on activities" were that pupils carrying out specific activities from the workbook or teacher's worksheets (95%), and pupils following detailed instructions to perform activity or experiment (83%).

On the other hand, in the use of problem-solving activities in the science classroom, the study found that the science teachers' beliefs were not quite congruent with their actions in the classroom. While the science teachers appreciated the importance of problem-solving skills in daily living, given opportunities to develop such skills were few in the classroom. Though most science teachers agreed that hands-on experiences were worth the time and effort, lesser numbers incorporated problem solving in their lessons. Nevertheless, a number of teachers expressed that problem solving helped to develop thinking skills in their pupils and that this was desirable.

Implications for primary school science instruction

When teachers embark on dramatic changes in the way they teach, they take a risk. Whether they are willing to sustain their efforts and whether instructional changes take root, will be influenced by the school environment. An important aspect is the school's recognition of teachers' efforts in trying out new teaching approaches and the collegiality among teachers to support such efforts.

One way to support science teachers is to provide them with relevant training courses on teaching problem solving. More importantly, another way to support them is to provide time for planning and interaction with other teachers. At these sharing sessions, teachers can reflect on their practice with their peers on what they do in class and share the extent of their success and ways to improve the teaching.

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