Scaffolding Cards: A Strategy for Facilitating Groups in Problem Solving

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Problem solving task design is not only the design of a non-routine problem to be solved by the students. Our task design also requires a supporting document, the practical worksheet, which would act as a cognitive scaffold for the students in the initial stages of the problem solving process before they can internalize the metacognitive strategies and automate the use of these strategies when faced with a new problem. A further enhancement of the scaffolding that can be provided by the teacher as she facilitates forty or more students working on the practical worksheet is a set of scaffolding cards. In this paper, we describe the cards and the preliminary use of these cards to facilitate problem solving for teachers in a professional development workshop.

The Practical Worksheet as Scaffolding for Problem Solving

Our research project *Mathematical Problem Solving for Everyone* (MProSE) has identified several issues in the literature in the international context as well as those in the Singapore local context that need to be addressed to facilitate the implementation of problem solving in schools. Our approach (see Toh, Quek, Leong, Dindyal & Tay, 2011a) still values the problem solving model of Pólya (1945) and the insights from Schoenfeld (1985). To aid in the implementation of problem solving in schools, we have come to the realization that the design of specific problems or problem solving tasks cannot be the only focus of problem solving but rather cognitive scaffolds (see Holton & Clarke, 2007) that allow students to solve a wider range of problems should also be an important focus. Accordingly, we turned our attention to the design of the *practical worksheet* that will be used as a cognitive scaffold in problem solving tasks (see p. 21-24, Toh, Quek, Leong, Dindyal & Tay, 2011a). The *practical worksheet* has been used in the various project schools with very promising results (see for example, Toh, Quek, Leong, Dindyal & Tay, 2011b).

Scaffolding Questions

What should the teacher do w hen students are working on a problem using the *practical worksheet*? As in the science practical where the teacher or technician provides help in setting up apparatus and in understanding the experimental setup and analysis with the view to learn the processes of science, the teachers in our project schools were instructed that any overt help would be towards improving the problem solving processes of the student seeking help.

To this end, we proposed three levels of help that a teacher can give to a student. The levels are hierarchical and one level should be given only after an earlier level has failed. In the crucial level which we call Level 0, the student learning and reinforcing the Pólya model is emphasised. The student may be asked if he or she knows what Pólya stage he or

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she is in, and what would one normally do in such a stage. In Level 1, *specific* heuristics are suggested to get the work moving. Level 2 is to be avoided as much as possible and is included only for the important aspect of ensuring that the self-esteem of the student is not seriously damaged by his perceived failure and helplessness on the problem. Here, we give problem specific hints, which essentially is a throwback to the 'usual' help afforded by mathematics teachers. The objective of the scaffolding is for students to internalize Level 0, and ask for Level 1, and to a much lesser extent Level 2, hints only when pressed for time.

We give examples of scaffolding prompts in Table 1 based on the Crossing the Bridge problem below:

> There are four persons who need to cross a bridge at night. The bridge is only wide enough for two persons to cross at once. There is only one flashlight for the entire group. When two persons cross, they must (i) use the flashlight; (ii) cross at the slower person's speed. The bridge will collapse in 17 minutes from the moment anyone steps on it. Here are the times in minutes each person takes to cross the bridge: 1, 2, 4, 10. How can all four persons get across the bridge within 17 minutes?

Table 1
Scaffolding Prompts for the Crossing the Bridge Problem

Level	Feature	Examples based on the *Crossing the Bridge* Problem
0	Emphasis on Pólya stages and control	What Pólya stage are you in now? Do you understand the problem? What exactly are you doing? Why are you doing that?
1	Specific heuristics	Try *dividing into cases*.
2	Problem specific hints	You should not insist on the '1' person making all the solo trips.

Scaffolding Cards to Facilitate Many Groups

A difficulty common to all teachers in the project schools was the lack of time to adequately provide help to all of the students. Students are typically given 20 to 30 minutes to solve a Problem of the Day during an MProSE lesson. The students are usually paired, resulting in as many as 20 groups in a class of 40. Our class observations and the teachers' reports agreed that many of the students could not be adequately helped within such a logistical constraint.

In line with our design experiment approach in MProSE, we discussed ways to facilitate many groups working on problem solving. No solution was tenable until quite recently when the idea of using prompt cards was mooted by a member of the team.

Cards measuring 9 cm by 6 cm were cut from vanguard sheets. On pink coloured cards were printed 'Polya Stages' as headers with more specific prompts such as the following included - Understand the Problem: Use heuristics, Devise a Plan: State your plan clearly, Carry out the Plan: Follow the plan stated earlier, Carry out the Plan: Need to change?, Check/Expand: Check using a different way, Check/Expand: Pose a new problem. On blue coloured cards were printed 'Heuristics' as headers with more specific prompts such as the following included - Restate the problem in another way, Think of a related problem, Work backwards, Aim for sub-goals, Divide into cases.

Teachers can use the cards to make up for the lack of time to actually talk to the students when they are working on a problem. The teacher may observe a group and decide if the group needs to be focused on a particular stage of problem solving. If so, he or she places a relevant 'Polya Stages' card on the desk and directs the students to work within

that stage. If the group is working within a stage and is not progressing at all, the teacher may place a relevant 'Heuristics' card on the desk and direct the students to use that heuristic. There are no cards for Level 2 specific prompts as the teacher will explain verbally to the student if the earlier scaffolding still proves unsuccessful. In this way, there should be enough time to facilitate each group at least two times.

The use of the scaffolding cards was tested in a professional development workshop for 20 teachers in the mathematics department of one of our project schools in December 2012. The teachers were given about 30 minutes to solve the Crossing the Bridge problem. They divided themselves into 5 groups of about 4 persons each. They were asked to write down their solution using a modified *practical worksheet* format which required them simply to section their writing under Polya stage headings of UP (Understand the Problem), DP (Devise a Plan), CP (Carry out the Plan) and C/E (Check and Expand). The third author facilitated the group work using the scaffolding cards as described above.

Feedback and Conclusion

Although it was 5 on a Friday afternoon, the teachers were generally quite enthusiastic about the problem and settled down in their groups to work on it. The facilitator was able to visit each group and drop a scaffolding card at least 3 times. All the groups had initial difficulty with the problem but all eventually solved it within 30 minutes. Many of the groups had time to pose new problems after being given the "Check and Expand: Pose a new problem" card.

A week after the session, we emailed the teachers requesting them to give us feedback via a questionnaire with 6 statements to which they could agree on a 1 (Strongly Disagree) to 5 (Strongly Agree) scale and a free response space. There were 11 replies out of 20 teachers after the 5-day deadline. All of the 7 teachers who actually taught the MProSE lessons earlier in the year and who were present at the workshop responded to the survey. The details of the 6 statements and the mean scores are shown below in Table 2.

Table 2
Scaffolding Cards Questionnaire

	Statements	Mean Score
1	The cards helped me personally in solving the given problem.	3.7
2	The cards can help me facilitate problem solving work in the classroom.	4.2
3	The Polya Stages cards channeled me to focus on working within a particular stage.	4
4	The Polya Stages card on Devising a Plan channeled me to clearly state my plan on which I would have to faithfully work on.	3.8
5	The Polya Stages card on Check and Expand (Pose a new problem) channeled me to pose a new problem.	3.9
6	Following the Heuristics card was crucial to progressing in the problem solving when I was stuck.	3.9

The results show that the scaffolding cards hold promise for overcoming the problem of the lack of time to facilitate problem solving for all the students in the classroom. For Statement (2), 9 teachers scored 4 and 2 teachers scored 5, indicating a general hope that the cards will be helpful when they teach.

Nine of the 11 teachers who replied also filled in the free response space and we group their impressions according to the areas of personal problem solving and facilitation of group work. Their comments on the use of the cards for personal problem solving were generally positive but guarded, which echoed their quantitative responses to Statements 1, 3, 4, 5 and 6. Many comments highlighted the usefulness of the cards in keeping them focused:

> … the Heuristic cards … offered me alternative ways of re-looking at the problem, staying focused on the various stages …
>
> … the physical presence of the cards (along with the written instructions) do help to direct my thoughts and make me focus even more.
>
> The Polya Stages card on Devising a Plan channelled my group to becoming aware that we need to state our plan.

The view that the cards indeed can help students focus on aspects of problem solving and also help teachers track and facilitate the students was even more positive and hopeful:

> … see the value of using the cards to get students to focus on/revisit a particular stage
>
> The Polya Stages cards do help the teacher in the tracking of the progress of the various groups – considering that different groups tackle the questions at differing paces.
>
> … the cards are useful for us to facilitate the problem solving work in the classroom as I do not need to spend too much time speaking to a particular group and … be able to spread myself out to the 8 or 10 groups ... With the cards, the students should also be able to focus better on what is required or what they need to look out for …
>
> … useful to facilitate communications between teacher and … groups in the classroom ... has worked well with teacher-learner[s], look forward to trying them in class.

Finally, two teachers cautioned that the cards might inadvertently stifle the initiative of the problem solver or that they would be a distraction:

> … however, the cards were also too obvious in giving us the 'answer' on what should the 'right' way be.
>
> However, for students who know about MProse, it can be a distraction instead when they are focusing to solve the problem …

The feedback obtained from these teachers, and their implications for effective use without compromising student initiative, will be shared with all the teachers in our project schools who will be incorporating the scaffolding cards in their MProSE lessons.

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