International Journal of Engineering Education Vol. 29, No. 2, pp. 280–290, 2013
Printed in Great Britain

0949-149X/91 $3.00+0.00

Long-term Innovative Problem Solving Skills: Redefining Problem Solving*

JENNIFER HARLIM and IOURI BELSKI
RMIT University, School of Electrical and Computer Engineering, GPO Box 2476, Melbourne VIC 3001, Australia.
E-mail: jennifer.harlim@gmail.com, iouri.belski@rmit.edu.au

Computer technologies are widely used to facilitate teaching of creative problem solving and to help engineers in their day-to-day work. To ensure effective utilisation in engineering practice, it is imperative to better understand the problem solving process itself. This research used an exploratory approach (Grounded Theory) to understand the complexities of engineering problem solving. Interview data from 22 engineers ranging from novice to experts, including 15 male and 7 female engineers were discussed. The participants believed that problem identification is the most crucial stage in good problem solving. 'Options' were identified as deterrents to long-term development of problem solving ability. It was established that it is necessary to boost self-efficacy of young engineers and make them willing to face challenges despite 'options'. Participants also suggested that conscious understanding and awareness of their own problem solving strategy is vital to the development of their problem solving skills. Findings from this paper provide new insights on how engineers develop their problem solving skills and can be used to improve existing theories on problem solving. These findings have implications on general educational strategy, as well as the development and implementation of computer technology for engineering problem solving.

Keywords: problem solving; problem identification; self-efficacy; long-life learning; transferability

1. Introduction and literature review

Since the start of the 21st century, technology in education has become prevalent. Computer-based tools are widely used in the teaching of creative problem solving within the engineering field, especially in areas of problem representation and idea generation [1]. While technology is expected to assist the problem solving process, long term effect of it on creative problem solving ability is still unclear. Some researchers suggested that if not deployed properly, computer-based tools may in fact have a negative impact on the development of students' creativity [2–3]. The understanding of basic concepts and skills which are essential for advancing problem solving skills is sometimes negated by the use of softwares [3]. Inappropriate application can even disrupt creative momentum [4]. While implementation of technology is to be encouraged, it should be done in a way to 'help engineers become the best thinkers they can' [3, p. 64]. In order to achieve effective utilisation of computer technology in problem solving, it is imperative to first understand how people go about solving problems.

A problem is often defined as an unusual situation that does not have apparent solutions [5–7]. It is well-established that problem solving requires a number of key steps: (i) understanding the problem, (ii) planning, (iii) execution and (iv) re-evaluation [7–9]. Therefore, good problem solvers are expected to possess well-developed abilities to identify and analyse a problem, select and organise relevant information, represent the problem, translate relevant information towards finding a solution, identify one or more solution strategies as well as to apply and evaluate these strategies [10].

Most research findings on problem solving come from fields of chess, mathematics, physics or puzzles [7–8, 11–12]. Problems in these domains are usually well-defined and only have one correct solution. Problems encountered by engineers in their day-to-day activities are ill-defined and answers are seldom right or wrong [13]. Engineering problems are complex and require creative solutions. Engineers are expected to be capable of identifying technical nature of the problem, achieving a solution and also evaluating the impact of the solution to a whole system/environment [14]. Consequently, it is imperative to unravel the specifics of problem solving in semantically-rich domains that mimic real-life engineering problems.

It is well-known that engineering education is specifically focused on developing students' ability to solve problems [15–16]. Despite significant body of research on teaching problem solving to engineers [17–22], a standard evaluation system has yet to be devised. The standard of good problem solving is often up to the researchers' interpretation [23]. A recent study suggested that good problem solvers are expected to possess the following traits: (i) they freely apply logic, (ii) use theoretical knowledge, (iii) undertake research, (iv) understand the problem

* Accepted 19 October 2012.

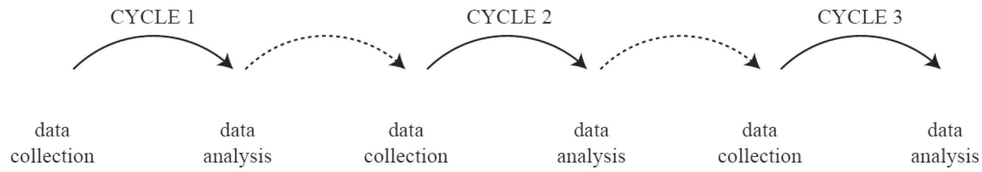

Fig. 1. Data collection and data analysis process.

well, (v) talk it over with others, (vi) plan, (vii) reflect and (viii) have an open-mind [24–25].

Previously the authors found that novice engineers expect good problem solvers to (i) have a holistic view on a problem, (ii) be open-minded, (iii) take sufficient time to solve problems and, more importantly, (iv) positively motivated [26]. It was also found that after learning problem solving tools, students' self-perception of their problem solving capacity increased. This impacts their motivation when facing problems. This self-perception of being capable, known as self-efficacy, impacts the willingness of students to face future problems [27]. This finding was supported by Bandura who proposed that 'people who have strong beliefs in their capabilities approach difficult tasks as challenges to be mastered rather than threats avoided' [28, p. 39].

2. Aim and methodology rationale

The aim of this research is to better understand problem solving process from the perspective of engineers. In particular, the purpose of this study is to foster better understanding of what good problem solving is and how engineers develop their problem solving ability. As problem solving performance involves numerous inter-dependent factors [29], a quantitative approach may not be sufficient to capture the complexities. An exploratory qualitative research approach, Grounded Theory [30] suggested by Corbin and Strauss [31] was used in this study. The following research questions are considered in this study:

- What is good problem solving from the perspective of engineers?
- How do engineers go about learning problem solving?

3. Data collection and analysis

Data presented in this paper was collected using taped semi-structured interviews conducted between 2009 and early 2011. Initial participants were recruited from a problem solving elective at RMIT University and also from various engineering organisations. These participants helped to recruit other participants via snowball-sampling. The interviews were carried out in cycles (Fig. 1) as in theoretical sampling. In theoretical sampling 'the researcher takes one step at a time with data gathering, followed by analysis, followed by more data gathering until a category reaches a point of "saturation"' [31, p. 146]. The focus of theoretical sampling is to follow up on leads that emerged from the data until no new themes are discovered. In this research, after each cycle, the interviews were transcribed and analysed by the main author. Interview questions were then adjusted to ensure that better data acquisition can be achieved in the next cycle.

The first cycle included 7 participants, the second 6 participants and the third cycle involved 9 participants. Data saturation was observed when carrying out the third cycle, resulting in a total of 22 engineers interviewed (Table 1). Participants ranged from novice to experts, including 15 male and 7 female engineers.

Interview questions were used as guides but the participants were encouraged to talk as freely as possible about the topic. Questions included how they went about solving problems, examples of good problem solvers and how problem solving can be learned or taught. As the interview progresses, additional questions were added to probe deeper for some of the underlying meanings in issues that the participants had raised. Questions such as 'why did you say that?' or 'what do you mean by

Table 1. Participants demographic

No. of participants	No. of work experience in full-time engineering field	Classification
6	0 years (Students and recent graduate with no work experience in the engineering field.)	Novice Class 1 (N1)
6	1–5 years	Novice Class 2 (N2)
3	6–10 years	Mid-level (M)
7	>10 years	Experts (E)

that?' were used. Throughout each interview, the main author would also paraphrase to check with the participant that her interpretations of what the participant said were accurate.

On top of carrying out analysis after each cycle, an overall analysis was also carried out when data collection concluded. Analyses were carried out in different ways and a number of times to get better depth of understanding of the data and to ensure rigorousness. For example, the transcripts were initially micro-analysed with the help of NVivo software to identify common themes. The main author also listened to all the recording again to get an overall understanding. Once emerging themes have been identified, the main author went through the transcripts to extract the relevant quotes. One of the main issues faced when using qualitative methodology is that analyses are subject to personal biases. In Grounded Theory instead of trying to suppress biases, the analyst is made more aware of personal preconceptions by the use of memos, diagrams and reflective journal. By engaging in self-reflection exercises while analysing data, a researcher is more likely to be more aware when he/she is slanting the data [31]. Verification of results with participants is paramount to ensure validity. This also enables a researcher to be more mindful of personal biases and help to negate personal assumptions in the analyses [31]. All these processes are consistent with the practice of ensuring rigour and validity in a qualitative approach [31–32]. Due to these reasons, it is impossible to rush into conclusion quickly when working with Grounded Theory. The use of this methodology requires longer time for thorough analysis. However, the use of Grounded Theory certainly allows a researcher to capture in-depth and rich data.

4. Findings

From the analyses, the following major themes emerged: consideration of problems as a whole, understanding the problem, the effect of assumptions/perception, learning through life-experiences, the detrimental effect of 'options', understanding is the key to learning and, the role of self-efficacy in transferability. The next sections would discuss and explain each theme and how they are related.

4.1 The importance of the problem identification stage

The participants believed that problems within the engineering fields require considerations into other areas, for example the environment. The participants interviewed in general agreed that good problem solvers are able to consider problems in all aspects (Fig. 2). This concept is further strengthened by a comment from one of the participant stressing that problem solving requires a full consideration of the limitations that exists in the problem:

> '. . . I've been a part of team of people who problem solve and brain storm on what are some ideas and *taking into considerations the limitations of what you can and can't do. Take into consideration timeframe, taking consideration how many people you've got to do that and what happens if you break one of rules*.' (M3)

In fact, participants indicated that understanding the problem in the first place is crucial for engineer-

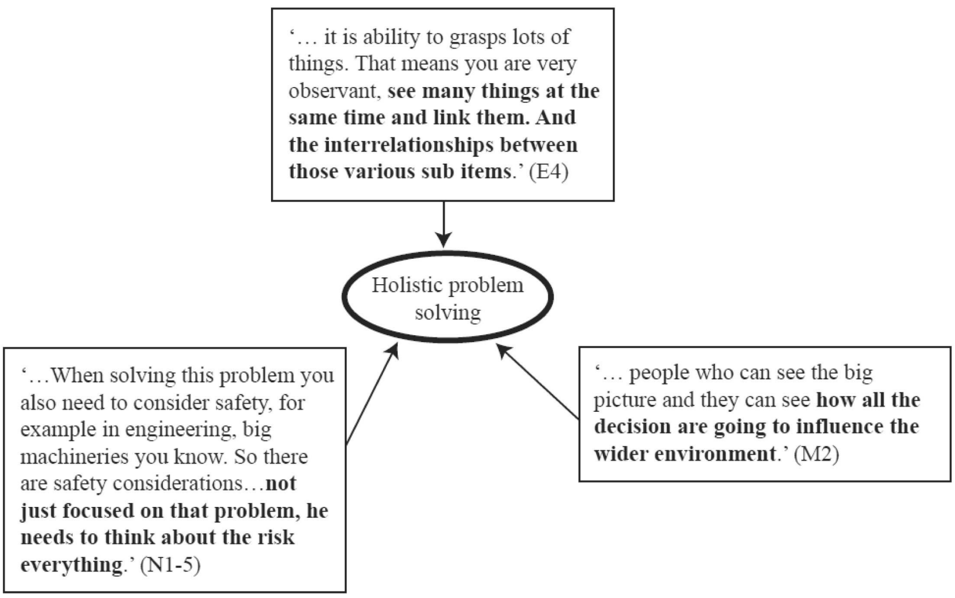

Fig. 2. Holistic problem solving theme and examples of quotes from participants.

ing problem solving (Fig. 3). They considered this aspect to be the key to whether or not the problem gets resolved well. The participants also recognised that the way a problem is interpreted is influenced by the problem solver's perceptions and assumptions (Fig. 4).

One participant's comment gave an example of how misanalyses and assumptions can impact a project outcome:

> '. . . only a couple of weeks ago actually we got a problem with one of the projects. So basically we almost finished the project but what we found . . . when we were about to test it whether it was working or not, we found another problem. . . We managed to find another problem because we tried to fix one thing. The 2nd problem actually was not analysed properly because it was out of the scope of the project. When we tried to do the project, we assumed that one of the testing procedures is actually working. But when we tested it we found out that it was actually not working. That's why we couldn't test all of the project.' (N2-1)

Comments from the participants suggest that the most important stage in effective problem solving is the problem identification stage.

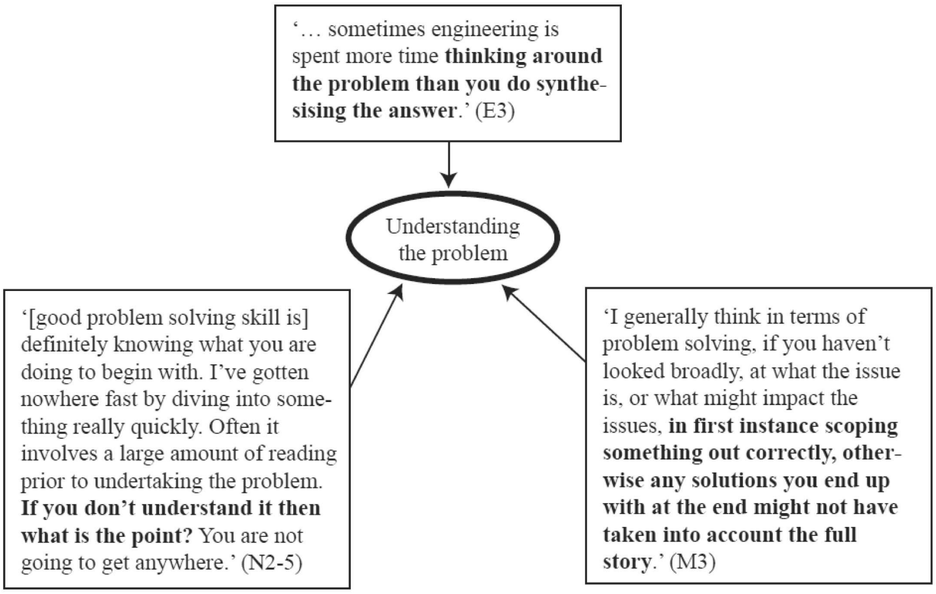

Fig. 3. The importance of understanding the problem theme and examples of quotes from participants.

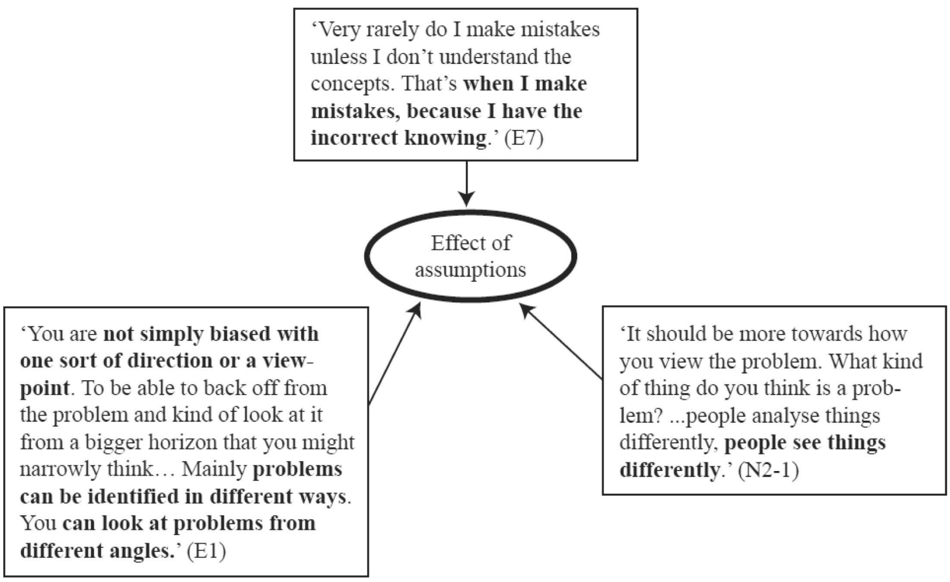

Fig. 4. The effect of assumptions in problem analysis theme and examples of quotes from participants.

4.2 The development of long-term problem solving skills for transferability

When the participants were asked about learning problem solving they indicated that the best learning comes from life experiences. Participants considered problem solving learned from life experiences to be of more value as seen in the comments below:

> 'It's something that you develop through life. You can't learn this in a course.' (N2-3)
>
> '[learning problem solving] I think life it does. Life does. I think not just courses, I think it's life' (E1)
>
> 'Life experience, attitude. And to a certain extent how you solved problems in everyday life. Even before you learned it in uni.' (N2-6)

One participant explained the difference between learning problem solving in a university setting and real life:

> '. . . in university we learn a bit of decision making. We do a lot of projects at [name of university], small projects, and presentations, which is helpful. *But the main thing is when dealing with real life, you can't make big mistakes*. In university if you make a big mistake *you can actually come back to your lecturer and say sorry*. Or your lecturer can fix it for you.' (N2-1)

Learning from mistakes is actually valued by the participants. Some of the participants considered making mistakes as an important process because when the way they understand things are constantly challenged, they learn better (Fig. 5). They believed learning in this mode results in a knowledge development that is more "sticky" in their brain. They considered learning that resulted from a change of perception deepens their understanding. Reponses from the participants suggest the more they are exposed to problems, the more they become aware of the way they approached it, and this awareness helped them to develop their problem solving skills as seen in the comment below:

> '. . . *if you were told or shown by someone I don't think it will ever work quite as well . . . you don't have the reasoning behind it*, while if you thought through a process all the little steps some worked some didn't but if someone tries to say think about this and think about this you are only going to think about the 5 things he told you. You might miss the sixth thing that he didn't tell you. Or the 6th thing that came up in a situation that is slightly different to the one he taught you about. Whereas maybe *if you had done that process yourself you have the ability to think outside the box a little more and consider it more broadly* . . . [in addition] *if you are left alone you have to search those things out for yourself a little bit more. That makes you a stronger engineer because you've sought that knowledge yourself rather than being told it*.' (M2)

The other difference between learning from life and learning in a formal educational setting is 'options'. 'Options' was identified as anything that makes problem solving easier such as external help (Fig. 6). 'Options' can also include policies that allow a problem solver to choose not to face challenges. In particular, 'options' can take away the need of understanding making knowledge or learning less "sticky" for future use. One student interviewed, despite having learned problem solving formally said:

> '*I didn't know anything*. I just answered whatever I came up with at first and I didn't even bother using the Su-field. I just think the answers first then use Su-field. . . *I'm like the person who relies heavily on others*. They know me. *I'm like the person who during exam time, most people come to me as they think I know the answers as I'll get it from someone*.' (N1-2)

In contrast, another participant stressed the importance of challenges to the development of problem solving skills:

> 'I found that the courses that *I got the most out of were*

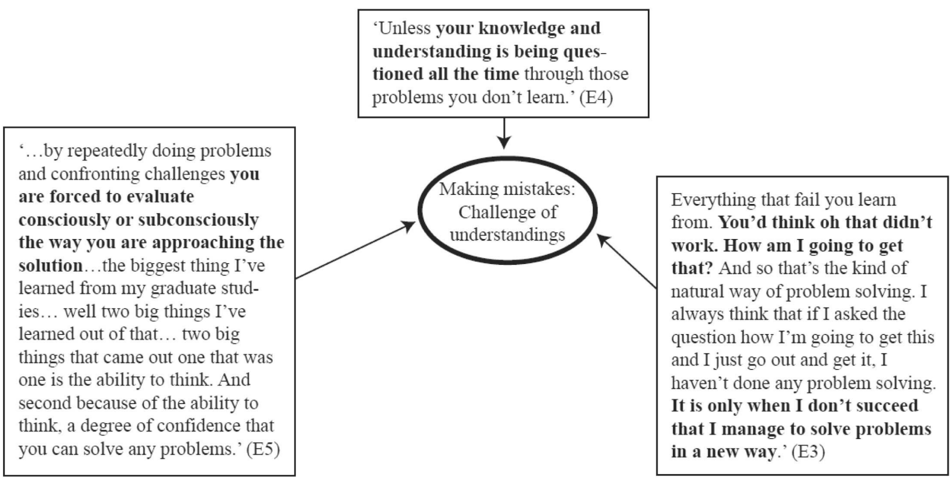

Fig. 5. Challenging understanding theme and examples of quotes from participants.

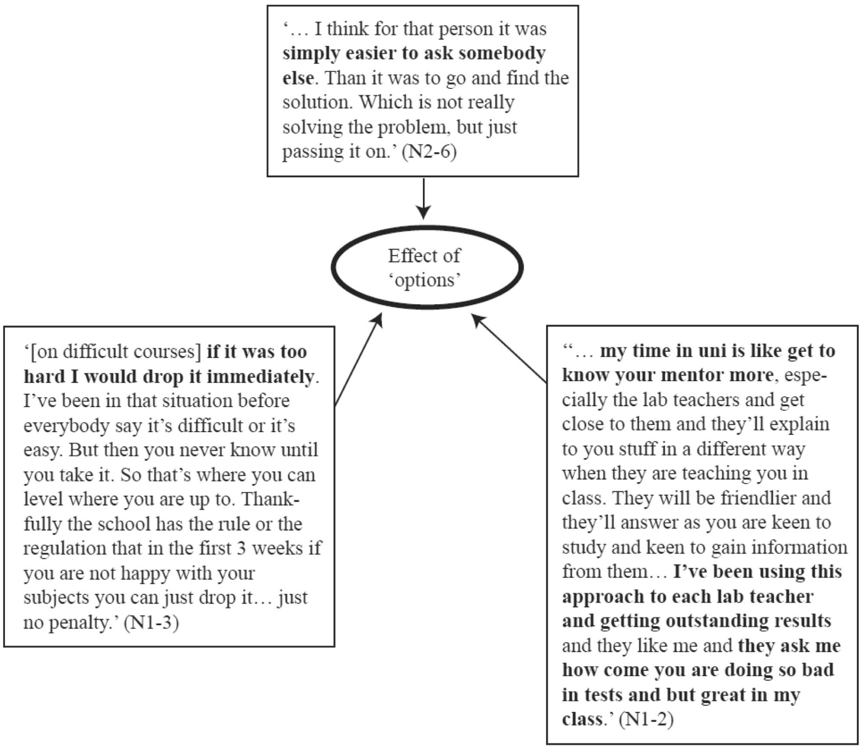

Fig. 6. Detrimental effect of 'options' theme and examples of quotes from participants.

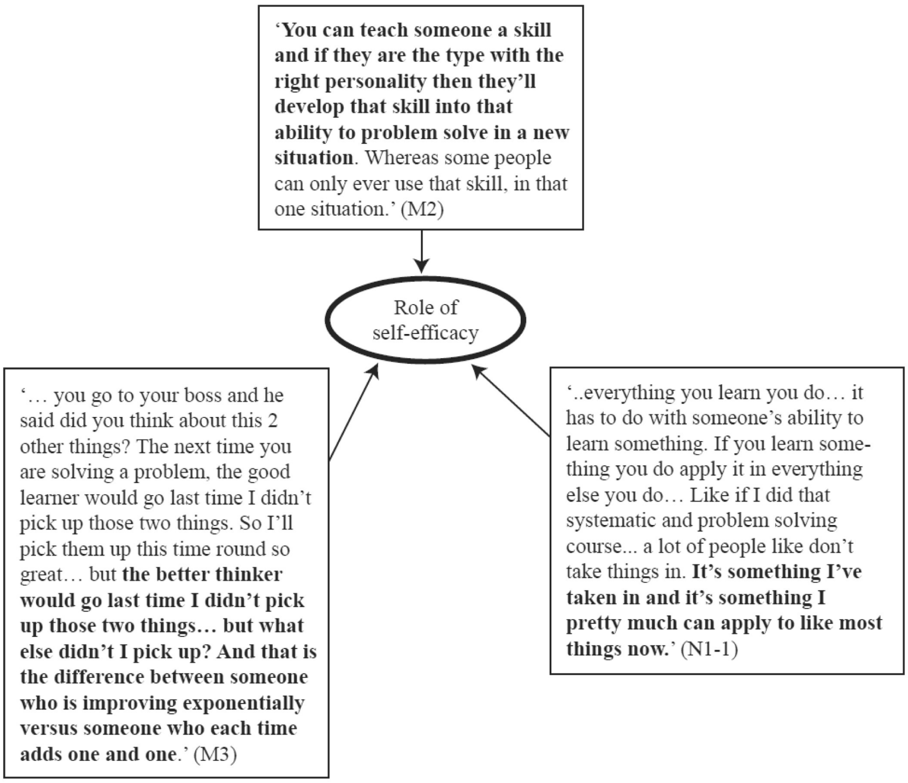

Fig. 7. Role of self-efficacy in transferability theme and examples of quotes from participants.

the ones where I was forced to do work myself and figure it out myself. I was a bad problem solver until I was forced to do it, to figure it out for myself.' (N2-5)

The participants also recognised that the key to developing problem solving skills is self-efficacy. Since transferable learning requires overcoming challenges, self-efficacy is considered to be vital. The participants believed that self-efficacy can drive the person's ability and motivation to learn and transfer the skills that they have learned from one problem to another (Fig. 7).

5. Discussion

The participants in this study considered good problem solving as ability to solve problems as a whole—treating any engineering problem as an integral part of a bigger system. This is particularly important as engineering problems seldom exist in isolation. In contrast to recent research findings [10, 24–25], participants in our research had a simplified view of what exactly good problem solving should encompass. Typically, good problem solvers are expected to be able to identify a problem, get a solution and evaluate the solution. Participants in our research were more specific—they insisted that the key to good problem solving rests in the problem definition stage. Similarly, Sobek II & Jain found strong relationships between client satisfaction, which they used as a measure for "good" problem solving, and activities related to problem definition [23]. Litzinger et. al. also suggested that problem solving errors are usually a result of poorly analysed problems [21]. Therefore, it is imperative that young engineers should learn proper procedures for problem identification.

Adams et. al. found that many academics think that students are focused too much on understanding questions rather than identifying and developing methods [24]. Our findings reveal that understanding problems well is pivotal for good problem solving. The capacity of a problem solver to establish sound solutions is determined by his/her ability to identify the problem correctly. Therefore, we recommend problem solving methodologies need to assist with problem identification and problem analysis. Specific problem solving methodologies such as TRIZ can assist with problem analysis. Tools within TRIZ help to break down complex problems enabling novices to view problems from different perspectives [26]. It was found that even simple strategies such as self-explanation can assist with problem analysis [21]. We conclude that it is vital for young engineers to learn methodologies that assist with effective problem representation.

We also discovered that problem representation is very much influenced by the assumptions and beliefs of a problem solver. It is well known that prior experience and domain knowledge impacts problem solving. We discovered that the problem solver's interpretation of the world significantly influences his/her understanding of the problem. This finding is supported by the work of Carlson & Bloom. They observed that expert decisions were

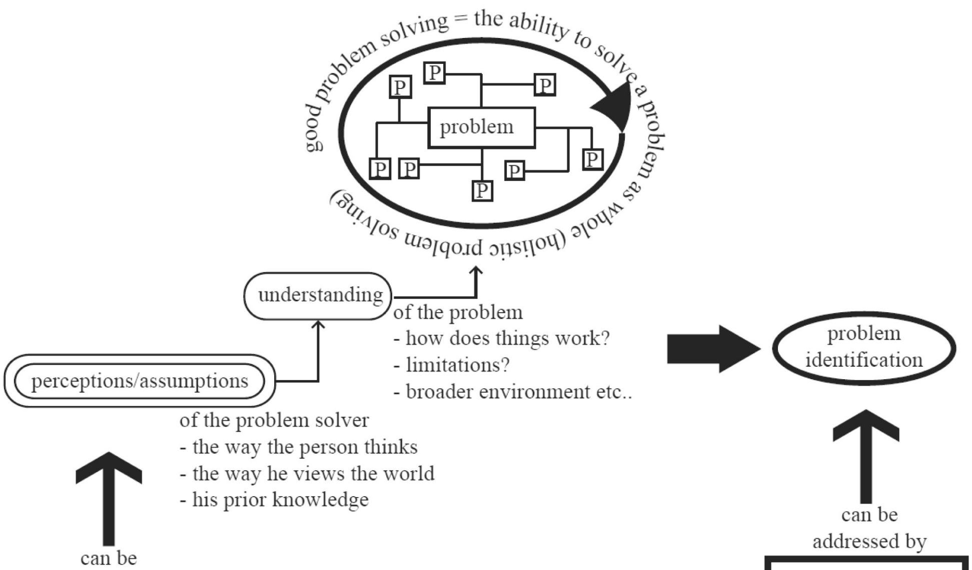

Fig. 8. Good problem solving and problem solving identification.

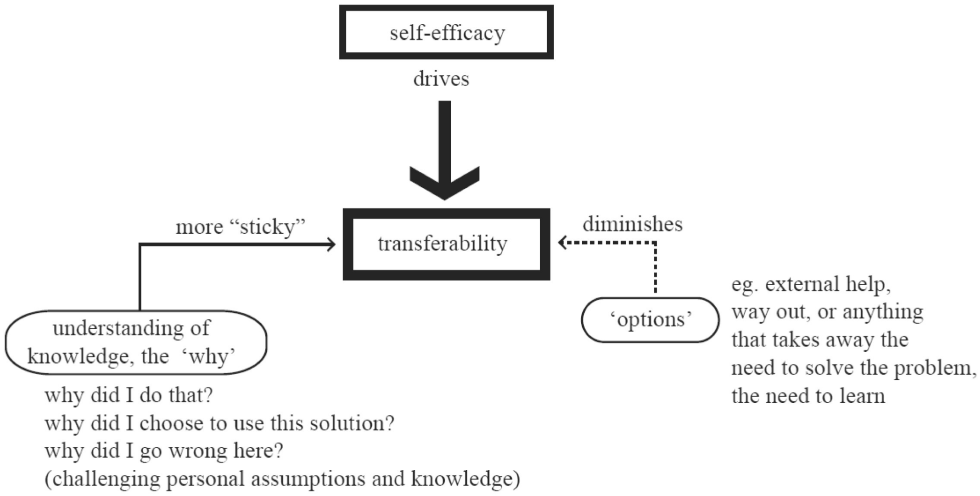

Fig. 9. Learning for transferability.

impacted by beliefs about mathematical concepts [7]. Open-mindedness, a theme that emerged from our earlier research and from the research of Adams et. al. [25–26] may minimise biases that a problem solver has. An open-minded problem solver is more likely to consider more aspects of a problem, thus carrying out better problem representation and is more likely to come up with more solution options. With open-mindedness, a problem solver is more capable of considering problems holistically without being bounded by his/her prior experiences. The links between the themes of good problem solving are summarised in Fig. 8.

Adams et. al. suggested that learning problem solving skills can be facilitated by group work, project work, and extensive practice. They also suggested introducing effective processes and methods, improving theoretical/practical knowledge as well as creating motivating learning environments as means of improving the education of engineers in problem solving [25]. Our research established that the way to enhance problem solving ability is not that simple. While problem solving methodologies can be taught, problem solving ability is learned. Two problem solvers can be taught the same methodology. Whether both are able to apply it into other context is dependent on the person's willingness and ability to learn what was taught. Participants in our study suggested that learning problem solving from life is more valuable in terms of developing their problem solving ability. This observation raised an interesting question of how learning problem solving from life differs to acquiring problem solving skills at university.

When learning in formal educational settings, 'options' are prevalent for learners. 'Options' refers to anything that offers learners opportunities to avoid challenges. In essence, 'options' enable a problem solver to take an easy way out or to solve a problem too quickly (and poorly). In education, strategies such as working in groups are highly encouraged. While working in groups helps novices to develop their communication skills, it can become a deterrent to the development of transferable problem solving ability when engineers become overly dependent on the help of other people. For example, one of our participants (N1-2) stated that his problem solving strategy is to ask people. He mentioned that he did not feel the need to learn as he can ask someone else. He also indicated that while he did well in areas he was helped, he did not succeed in areas where he had to apply knowledge on his own. This example indicates the lack of transfer when people rely on 'options'. Participants in the study of Adams et. al. considered talking or asking people for help as part of the problem solving process [25]. While we believe that consulting others is important in assisting problem solvers to stay open-minded, we advise problem solvers to be cautious when using people's help as a sole strategy for problem solving.

Ability of a learner to propose answers quickly is often commended at university. The emphasis on getting a solution quickly can be misinterpreted by a learner discouraging him/her from sound understanding of the importance of a proper solution process. We believe that this is detrimental as it negates the need to really understand the reasoning behind the solutions. Our data suggest that understanding of reasoning during problem solving as well as thinking about the solution process makes learning effective, enabling better transfer. When a problem solver gets to the right answer too quickly without really understanding the rationale behind the solution, schema acquisition is hindered [11]. Our data also suggests that this may inhibit transferability.

The use of technology can be perceived by problem solvers as 'options' too. It was reported that computer-based tools that were usually made available as part of engineering training were used without much understanding of what these tools really do [22]. By suggesting a quick design solution, computer software may obscure the need for students to learn basic domain skills that they require in engineering problem solving [2–3]. Moreover, Jandt and Schueler-Hainsch reported the use of software without some knowledge of the problem solving methods underpinning the software can be ineffective [4]. This finding is consistent with opinions of our participants who suggested the understanding of how they solve problems is vital to the development of their problem solving skills. Thus, we propose problem solving methodologies that underpin software tools need to be made explicit to the users. When problem solving methodology has been well comprehended, engineers become more aware of the underlying principles and the limitations of software. This is also more likely to promote the understanding that technology is a tool that can assist problem solving, but not a substitution for actual problem solving itself.

Carlson and Bloom noticed self-belief impacts the decision making process of experts [7]. This research identified self-efficacy, the self-belief of the problem solvers' ability to solve problems, as the key driver of transferability. It is quite possible that high self-efficacy can overcome the negative influence of 'options'. Bandura argued that self-efficacy *'contributes to the acquisition of knowledge and development of subskills, as well as drawing upon them in the construction of new behaviour patterns. . . through the proactive exercise of efficacy belief in self-development, capacity is converted to capability'* [28, p. 61]. This is fully supported by our data. Nonetheless, we need to be aware that while self-efficacy can improve transferability, 'options' can also negate self-efficacy:

> 'People may possess the skills needed to accomplish a task and a strong sense of efficacy that they can execute them well but still choose not to perform the activities because they have no incentive to do so . . . they are prevented by external impediments from performing to the level of their efficacy beliefs.' [28, p. 68]

As mentioned previously, problem identification is affected by the problem solvers' assumptions. Therefore, it is likely that a problem solver will be able to understand a problem better and solve it more effectively by changing his/her perceptions about it. This was supported by our participants who suggested that the changes in the way they perceive problem occur through continuous re-evaluation of their assumptions and knowledge. This process also helped with their problem solving skill development. These findings are supported by Bandura:

> '. . . transforming thoughts into action operates through a conception-matching process. Conception of skills serves as guides for developing competencies and as internal standards for improving them. Conceptions are rarely transformed into appropriate performances without error on initial attempts . . . observing one's enactments provides the information needed to detect and correct mismatches between conception and action. If people do not monitor what they are doing, efforts to implement a good conception will not produce proficient action.' [28, p. 26]

The relationships between self-efficacy, 'options', understanding of knowledge, and transferability are presented in Fig. 9. Reiterating what our participants have suggested, the conscious awareness of assumptions, knowledge, strategy and problem solving enables the problem solver to build up his/her knowledge. We believe this enables the problem solver to utilise knowledge more effectively even in new situations.

There are several implications in our findings on educational strategies for teaching problem solving to engineers. Problem solving strategies taught to young engineers should focus on problem representation. Methodologies that focus specifically on problem identification should be taught to undergraduate students explicitly. We believe that when a methodology is taught explicitly, learners are more likely to be aware of the problem solving process and the reasoning behind the solution steps. We found that awareness of how one goes about solving problems is vital in long-term development of problem solving skills. While, methodology can be taught, assumptions, which impact problem identification, are personal to the problem solver. Instead, it is important to boost self-efficacy so that young engineers are willing to face challenges despite the presence of 'options'. Learning a systematic methodology can lead to better self-efficacy. In addition, instead of focusing on getting the right answer, young engineers should be made aware that making mistakes is a part of learning, and, thus, personal reflection is paramount. The constant re-evaluation of assumptions and beliefs is vital to the development of transferable problem solving ability.

Specific to the utilisation of technology in innovative problem solving, we caution that technology should be used with thought and care. Given the ease of getting to solution ideas using computer-based tools, it is important to make sure that computers will not become an 'option'. Technology is a tool to enhance problem solving, but not a substitution for it. Instead of focusing on idea generation only, we recommend that computer-based tools should focus more on helping users to identify problems better. Computer-based tools can assist with problem representation by making rich complex links that exist within the engineering problem more visible to the users. Computer-based tools should also tease and question users on underlying assumptions making them aware of their own biases. The basic understanding of the methodology is crucial even if it has been adapted for computer use. The rationale behind and limitations of the technology should also be clearly understood by the users.

6. Conclusion

The findings of this research offers new insights on what engineers perceive as good problem solving and how they develop problem solving skills. The outcomes of this research can be used to improve existing models on problem solving. Two major aspects have been discussed in this paper: the role of problem definition in engineering problem solving and the ways long-term development of problem solving skill can be enhanced for engineers.

As this paper is part of an ongoing PhD research, findings are continuously refined. Comparisons were also made between the responses of the novice and expert engineers in the study. Other themes with deviation in opinions from the different groups emerged from the rich data pool but were not discussed in this paper. While Grounded Theory technique has helped us deepen our understanding of problem solving from perspective of engineers, further verification needs to be carried out. This is to ensure the findings are not limited to the interview sample size. A pilot questionnaire is being designed and will be disseminated to capture data from more engineers. Results from the questionnaire need to be analysed using confirmatory factor analyses and compared against the interview data. Further options of triangulation of data are being considered. Despite some limitations in this research, findings presented in this paper have implications on educational strategies as well as on development and implementation of computer-based tools to achieve effective and long-term improvement in both problem solving skills of engineers and creative outcomes of their work.

References

1. K. Holt, Computer-aided Creativity in Engineering Design, *Journal of Engineering Design*, **4**, 1996, pp. 371–376.
2. J. Walther, B. F. Robertson and D. F. Radcliffe, Avoiding the potential negative influence of CAD tools on the formation of students' creativity, in *AaeE—Connecting Teaching, Research and Industry through Engineering Education*, Melbourne, Australia, 2007.
3. P. Brown, CAD: Do Computers Aid the Design Process After All?, *Intersect*, **2**, 2009, pp. 52–66.
4. M. Jandt and E. Schueler-Hainsch, The introduction and application of TRIZ in industrial businesses in Germany—an investigative study, in TRIZ-future conference, Frankfurt, Germany, 2007, pp. 185–189.
5. A. Tallman and L. N. Gray, Choices, Decisions, and Problem Solving, *Annual Review of Sociology*, **16**, 1990, pp. 405–433.
6. B. Yeap, *Metacognition in Mathematical Problem Solving*, presented at the Australian Association for Research in Education, Adelaide, Australia, 1998.
7. M. P. Carlson and I. Bloom, The cyclic nature of problem solving: An emergent multidimensional problem-solving framework, *Educational Studies in Mathematics*, **58**, 2005, pp. 45–75.
8. G. Polya, How to Solve It: A new aspect of mathematical method, 2nd ed. USA: Princeton University Press, 1945.
9. I. Belski, *Seven Steps of System Thinking*, in 13th Annual Conference and Convention, Canberra, Australia, 2002.
10. S. Hambur, K. Rowe and L. T. Luc, *Graduate Skills Assessment: Stage One Validity Study*, C. D. o. E. S. Training, Ed., ed: Australia Council for Educational Research, 2002.
11. M. L. Gick, Problem-solving strategies, *Educational Psychologist*, **21**, 1986, pp. 99–120.
12. J. Larkin, J. McDermott, D. P. Simon and H. A. Simon, Expert and novice performance in solving physics problems, *Science*, **208**, 1980, pp. 1335–1342.
13. D. H. Jonassen, Instructional Design Models for Well-structured and Ill-Structured Problem-Solving Learning Outcomes, *Educational Technology Research and Development*, **45**, 1997, pp. 65–94.
14. Engineers Australia, *Australian Engineering Competency Standards—Stage 1* in Competency Standards For Professional Engineers ed. Canberra, 2009.
15. S. Beder, Beyond Technicalities: Expanding Engineering Thinking, *Journal of Professional Issues in Engineering*, **125**, 1999, pp. 12–18.
16. G. L. Roth, Decision Making in Systems Engineering: The Foundation, *IEEE*, **1**, 2007, pp. 236–246.
17. B. Alexander and C. Izu, *Engaging weak programmers in problem solving*, presented at the IEEE EDUCON Education Engineering—The Future of Global Learning Engineering Education, Madrid, Spain, 2010.
18. I. Belski, Teaching Thinking and Problem Solving at University: A Course on TRIZ, *Creativity and Innovation Management*, **18**, 2009, pp. 101–108.
19. R. Paton, Making problem-solving in engineering-mechanics visible to first-year engineering students, *Australasian Journal of Engineering Education*, **16**, 2010, pp. 123–137.
20. C. Benjamin and C. Keenan, Implications of introducing problem-based learning in a traditionally taught course, *Engineering Education*, **1**, 2006.
21. T. A. Litzinger, P. Van Meter, C. M. Firetto, L. J. Passmore, C. B. Masters, S. R. Turns, G. L. Gray, F. Costanzo and S. E. Zappe, A Cognitive Study of Problem Solving in Statistics, *Journal of Engineering Education*, vol. October, 2010.
22. T. R. Kurfess, Producing the Modern Engineer, *International Journal of Engineering Education*, **19**, 2003, pp. 118–123.
23. D. K. Sobek II and V. K. Jain, *The Engineering Problem-Solving Process: Good for Students?*, in 2004 American Society for Engineering Education Annual Conference & Exposition, Salt Lake City, UT, 2004.
24. J. Adams, S. Kaczmarczyk, P. Picton and P. Demian, *Problem solving and creativity in engineering: Perceptions of novices and professionals*, in World Congress on Engineering and Computer Science, San Francisco, USA, 2009.
25. J. Adams, S. Kaczmarczyk, P. Picton and P. Demian, Problem solving and creativity in engineering: conclusions of a three year project involving reusable learning objects and robots, *Engineering Education*, **5**, 2010, pp. 4–17.

26. J. Harlim and I. Belski, *Young engineers and problem solving: The impact of learning problem solving explicitly,* in AaeE—Past, Present, Future—the 'keys' to engineering education research and practice, Sydney, Australia, 2010.
27. J. Harlim and I. Belski, *Learning TRIZ: Impact on confidence when facing problems*, in 11th ETRIA World TRIZ Future Conference, Dublin, Ireland, 2011.
28. A. Bandura, Self-Efficacy: The Excercise of Control, 11th ed. New York, USA: W. H. Freeman and Company, 1997.
29. L. D. English, *Interdisciplinary Problem Solving: A Focus on Engineering Experiences*, in 31st Annual Conference of the Mathematics Education Research Group of Australalasia, Brisbane, Australia, 2008.
30. B. G. Glaser and A. Strauss, The Discovery of Grounded Theory: Strategies for Qualitative Research, 6th ed. New Brunswick, USA: Aldine Transaction, 1967.
31. J. Corbin and A. Strauss, Basics of Qualitative Research, 3rd ed. California, USA: Sage Publications, Inc., 2008.
32. S. J. Tracy, Qualitative Quality: Eight Big-Tent Criteria for Excellent Qualitative Research, *Qualitative Inquiry*, **16**, 2010, p. 837.

Jennifer Harlim is a PhD Candidate at the Royal Melbourne Institute of Technology, Australia. Her research is in the area of Problem Solving for Engineers: Measures and Transferability. She is also interested in the area of research methods.

Iouri Belski is a professor of engineering problem-solving at the Royal Melbourne Institute of Technology, Australia. His areas of research interest include thinking and problem-solving, learning, memory, creativity and Theory of Inventive Problem Solving (TRIZ). Iouri is a recipient of 2009 Australian Award for Teaching Excellence.