# Problem solving and creativity in engineering: conclusions of a three year project involving reusable learning objects and robots

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**ABSTRACT.** The necessity for creative problem solving skills within the sciences and engineering are highlighted in benchmark and policy statements as essential abilities. None of these statements, however, offer any guidance on how these skills might be fostered, let alone assessed.

This paper presents findings from the second cycle of an action research project to develop a dedicated creative problem solving module for first year engineering undergraduates. In the module problem based learning (PBL) techniques have been used with Lego Mindstorm NXT robots to develop creative problem solving skills. The focus of the module has been on developing process skills as opposed to the simple methodical solving of routine problems. Process skills have been introduced and mediated by the use of reusable learning objects (RLOs) within a virtual learning environment (VLE). Separate RLOs have also been used to develop skills in using the robots.

The action research cycle has been informed by a parallel project involving interviews designed to explore the perceptions of students, academics and professional engineers of creative problem solving. Phenomenography has been used as the main research tool.

Student feedback through online questionnaires, focus groups, classroom-based observation and interviews indicates that the module, and its means of delivery, has proven successful in improving creative problem solving skills. It also highlights the value of developing process skills within a practical and motivational environment.

***KEYWORDS:*** *Action research, Creative problem solving, Learning by questioning, Lego Mindstorm NXT robots, Reusable learning objects*

Creative potential and the ability to solve problems are identified as essential characteristics for both novice undergraduate engineers and qualified engineering professionals in UK benchmark statements (Engineering Council UK, 2005, QAA, 2006):

> The creative way of approaching all engineering challenges is being seen increasingly as a "way of thinking" which is generic across all disciplines. […] They [engineering undergraduates] will want to solve problems and have strategies for being creative, innovative and overcoming difficulties by employing their knowledge in a flexible manner (QAA, 2006).

Creativity within the sciences, including engineering, is also identified, both explicitly and implicitly as an important driver in recent UK reviews relating to economic prosperity and government science and innovation policies (Leitch, 2006; Sainsbury, 2007).
Similarly, in Europe problem solving and creativity are presented as important competencies in the requirements for European Engineer (Eur. Ing.) designation (FEANI, 2000).
What these statements fail to do, however, is to offer guidance on how problem solving and creativity might be fostered and taught, let alone how they might be assessed.
It is against a backdrop of benchmark statements and policies that educators must devise and implement strategies for developing, enhancing and assessing creativity and problem solving skills within the sciences and engineering.

## Related research

Strategies for teaching problem solving and for the development of creativity can be found in numerous publications (Woods, 1977; Felder, 1998; Dewulf, Baillie, 1999; Felder, 2006). Wankat and Oreovicz (1993) suggest however that, while the foundation of good engineering education is the development of transferable problem solving skills, lecturers and professors prefer to concentrate on teaching subject content rather than showing the processes involved in problem solving. Houghton (2004) proposes that problem solving is 'what engineers do'. He contends that problem-solving skills may be the most important thing we can teach our students.

It is possible to identify, from both anecdotal sources and more defined evidence, that deficiencies continue to exist in the teaching of creative problem solving skills (Dartmouth, 1997; Chu, Lai, 2002) and that the traditional models and methods of teaching used in engineering education may be outdated and not provide sufficient motivation for engineering undergraduates of the 21st century (Felder, 2006).

There are a host of different strategies for problem solving which have been reviewed in detail by Woods (1977). Woods' own method, similar to that of Polya (1957) but with one additional step (step 2), considers problem solving as a simple five stage process:

1. Define
2. Think about it
3. Plan
4. Carry out plan
5. Look back

Valuable research also exists on the characteristic differences between expert and novice problem solvers, which can inform our understanding of developing creative problem solving skills in the classroom (Selden, Selden, 1997; Breslow, 2001).

Teaching of the problem solving process in the classroom can be achieved in a number of ways. One method is *thinking aloud in pairs problem solving* (TAPPS), where problem solving process skills are developed through the interaction of the problem solver and a listener (Lockhead, 1979; Stice, 2007). Other strategies for developing discrete stages of the process include the use of brainstorming techniques for idea and solution generation, Gantt charts for planning and implementation and evaluative checklists for evaluation and reflection (Mackenzie et al., 1999), amongst many others. Another important and well recognised method for developing problem solving skills in the classroom is the use of problem based learning (PBL) exercises.

In PBL the handling of a problem drives the whole learning of the student (Palmer, 2002; Jackson, 2003; Kahn, O'Rourke, 2004). The curriculum is structured as a problem or series of problems, as opposed to a systematic presentation of subject content. It must be noted, however, that problem based learning is distinctly different from problem *solving* learning, with the former being used

to develop *processes* in a wider context rather than *products* in a confined environment (Savin-Baden, 2000).
PBL exercises are described as a 'component method' under the umbrella of *instructional design* (Reigeluth, 1983). Componential methods can be executed in different ways and are made up of different components or features. So, for a PBL activity these components might include: setting the problem scenario, forming the teams, providing support, allowing reflection on individual performance etc.
*Instructional design* and *learning design* theories are design-orientated and can be considered as one approach to the operationalisation of cognitive education and strategies. They are concerned with developing guidelines about which instructional methods and models to use in a given situation or context (ADL, 2007; Reigeluth, 1983; Gagne, 1992; Tennyson et al., 1997; Koper, 2006).
From an educational perspective, current models or simulations developed as part of instructional design or learning design (including those that utilise PBL exercises, and Enquiry Based Learning (EBL) activities that extends PBL to incorporate small-scale investigations and project work) lend themselves to the application of learning objects (ADL, 2007; Rossano et al., 2005; Koper, 2006).
The concept of learning objects, and in particular their reusability in different contexts, is relatively new to teaching and learning, and application and research in this area is growing rapidly (CETL-RLO, 2007).
We must begin with a basic understanding of the concept of learning objects. One working definition is:

> Learning Objects are defined [here] as any entity, digital or non-digital which can be used, re-used or referenced during technology supported learning. Examples of Learning Objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organisations or events referenced during technology supported learning (LTSC, 2007).

Two useful metaphors offered by Wiley (2001) present learning objects in a simplistic model as pieces of Lego and, in a more developed model, as an atom.
Whilst learning objects are generally employed as 'content chunks',

learning theorists are pushing for their use and reuse in case based problem solving scenarios such as those developed for PBL (Wiley, 2004). It is this potential for the use of *reusable* learning objects in the context of mediating problem solving and developing creative process skills within a PBL scenario that offers potential, and forms part of the originality of this research study.

This paper describes the second cycle of a three year action research project to develop a creative problem solving module for first year engineering undergraduates. The work has involved two cycles of action research over two academic years and has been kindly funded by initial and continuation funding from the Higher Education Academy Engineering Subject Centre at Loughborough University. Findings from the first cycle have been disseminated at a number of conferences (Adams, Turner, 2008b; Adams, Turner, 2008a; Adams et al., 2008b).

In the project, Lego RCX and, more recently, Lego Mindstorm NXT robots have been used as a way to motivate engineering students to develop creative problem solving skills within a PBL scenario. Mediation of the creative problem solving process has also been an important part of the project, and this has been enabled in the first cycle through classroom-based sessions and activities, and in the second cycle through the use of reusable learning objects (RLOs) within a Blackboard based virtual learning environment (VLE).

The development of module content and delivery has been informed not only by themes identified within the literature but also by a parallel project involving a series of interviews to identify the perceptions of engineering students, academics and professionals. The purpose of the interviews was to investigate the perceptions of, and characteristic similarities and differences between, expert and novice engineering problem solvers. Early findings from the interviews have been presented at a number of conferences and a final analysis is now complete (Adams et al., 2007; Adams et al., 2008a; Adams, 2009).

## Methodology

Two main research methods have been used in this study: action research and interviews.

The action research involved first year engineering undergraduates

at the University of Northampton in the development of a dedicated creative problem solving module.
Action research has been chosen as the main research methodology due to its suitability for researching 'social practices' such as the development of problem solving and creative thinking skills (Carr, Kemmis, 1986). Each cycle of action research has involved the processes of planning, acting, observation and reflecting. It is acknowledged that this process is a recursive spiral and that more than one iteration is required for the process to be effective. Two cycles of action research over two consecutive academic years have been undertaken in this study and this report describes the second cycle. The work has already continued into a third cycle.
For the second cycle a PBL approach using an instructional design model has been adopted and developed for the module (Reigeluth, 1983). This is illustrated in Figure 1.

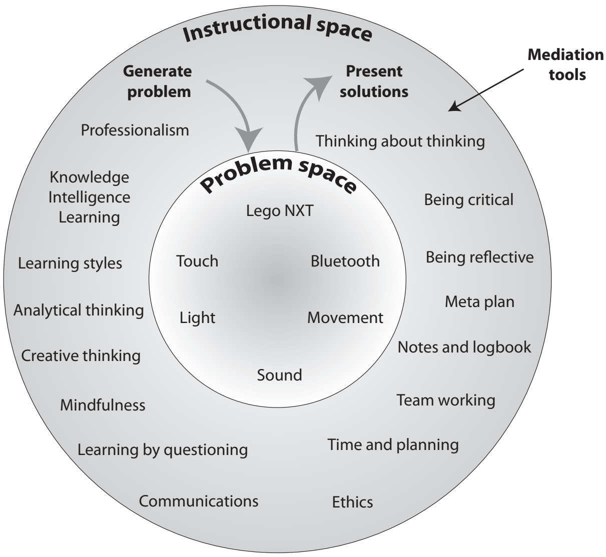



Figure 1. Instructional design PBL model using learning objects

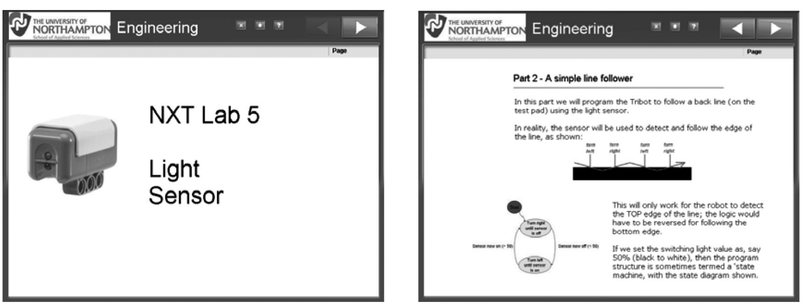
In the model, learners operate in two domains (termed 'spaces') during the creative problem solving process. In the 'problem space' they work directly on the problem and enter the 'instructional space' when they encounter a skills or knowledge deficiency. The instructional space also provides tools to mediate the problem-solving process. Instructional content in each of the spaces is provided using reusable learning objects (RLOs) (Wiley, 2001, 2004).

In the project, the problem space is represented by a problem that the students have generated themselves and have attempted to solve using Lego NXT robots. Also within this space are instructional items relating to the basic features and functions of the robots, along with practice exercises. Items in the instructional space are related to developing both cognitive skills and abilities, and also skills and techniques that are relevant to the typical stages of the problem solving process: define, think about it, plan, carry out plan, look back (reflect) (Woods, 1977).

RLO content has been informed by the first cycle of action research, previous published research and findings of the interviews comparing professionals with novices. Each title in Figure 1 represents a separate RLO. Additional RLOs have also been made available to introduce the module and to set the rules for generating the problem space.

RLOs have been created in a software authoring tool called Lectora (from Trivantis Corp.). Each RLO is a self-contained learning unit and typically consists of 10 to 12 screen-readable pages containing text and diagrams. Lectora also allows for the integration of audio and video content, as well as online and offline testing, although this has not been used in the study. RLOs can be produced in various formats, including SCORM (Shareable Content Object Reference Model) for easy integration into a VLE. SCORM is a standard for developing, packaging, delivering and sharing electronic learning content for use in a Managed or Virtual Learning Environment and was developed by Advanced Distributed Learning (ADL). RLOs have further been made available in zipped HTML format and as a self-executable file. Various formats have been used in the project and RLOs have been made available within the University of Northampton Blackboard-based VLE (NILE), on a memory stick and also in weekly emails to students. Screen shots of typical RLOs are shown in Figures 2 and 3.

Figure 2. Typical RLO
*(NXT Light Sensor)*



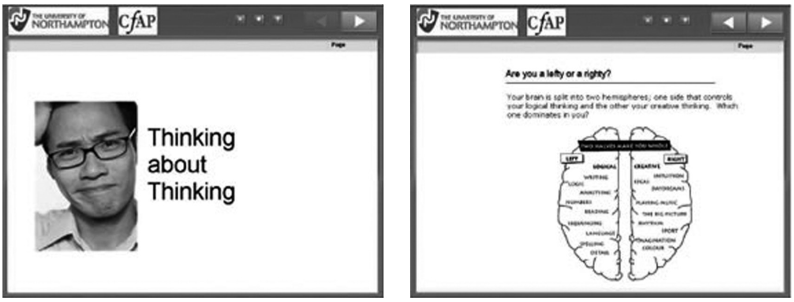



Figure 3. Typical RLO
*(Thinking about Thinking)*

SCORM compliant RLOs (which were integrated into the VLE) were enabled with tracking and performance reporting information for inclusion into the VLE's electronic record-keeping Gradebook.
Students were provided with the opportunity of 22 timetabled one-hour class contact sessions (autumn and spring terms) in which they could access the Lego Mindstorm NXT robots and the VLE. Access to the VLE (and RLOs) was also available outside this time, although access to the robots was restricted. Ten first year engineering students regularly attended the sessions and undertook the robot problem, although the VLE (and RLOs) were also made available to undergraduate engineering students across all three years (a total of 97 students had access). Attendance was on a voluntary basis since the module does not currently bear credit, although students were encouraged to attend by being given a memory stick.
In order to generate the problem space, students were provided with guidance (ground rules in the form of RLOs) on how to devise their own problem. They were also required to devise some judging criteria. Metaplan (usually employed as a problem-solving tool) was used to generate and agree the common problem for all students (working in sub-groups) to solve. Figure 4 shows students using Metaplan and generating the problem.

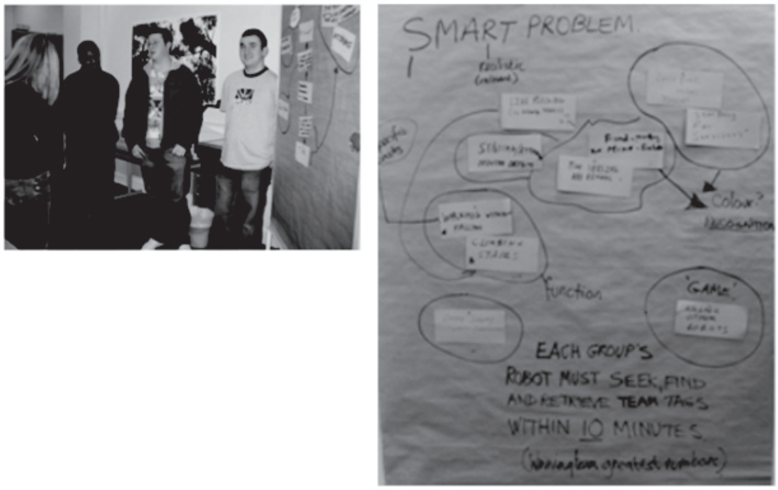



Figure 4. Students using Metaplan to generate 'problem space'

The problem generated by students was to identify and retrieve coloured 'tags' in the corner of a bounded area within a ten minute period. The winning team was the one who retrieved the most tags. As an incentive, small prizes were awarded. Programming of the Lego robots was done using the visual Lego NXT-G software supplied with the robots. A number of useful NXT-based books were also made available to the students in the library and in the contact sessions (Kelly, 2007; Prochnow, 2007; Perdue, 2008; Kelly et al., 2009). The engineering department has eight Lego NXT robots accessible by the students (four with boy's names and four with girl's names).

Throughout the process of solving the problem, students were expected to keep an engineer's log book. Guidance for this was provided in an RLO.

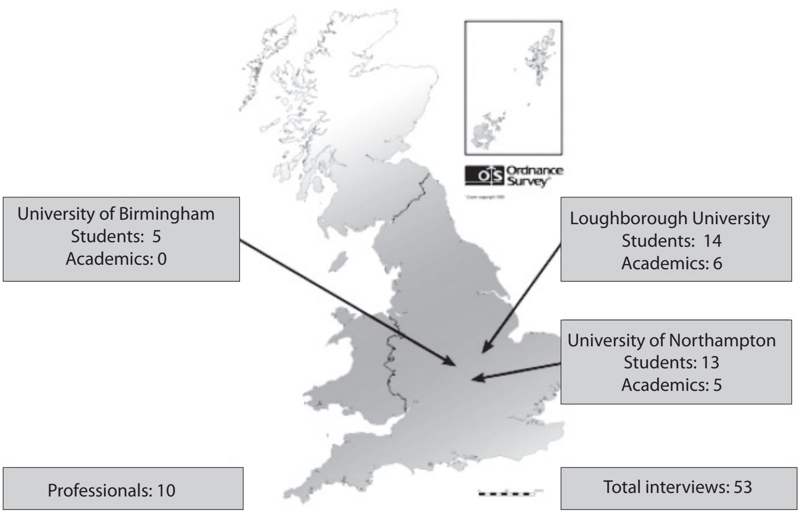
In addition to the action research, a substantial study involving 53 semi-structured interviews has been carried out with engineering undergraduates, academics and professional engineers. The purpose of the interviews was to investigate characteristic similarities and differences between the perceptions of experts and novices to problem solving and creativity in engineering. Findings from the interviews have been used to influence the development of the action research cycles. Participants were asked three open-ended questions:

1. What qualities do you think make a good engineering problem solver?

2. What do you understand by ‘creativity’ in relationship to engineering?
3. How do you think that these skills can be improved in undergraduate engineers?

The interviews were undertaken during the period January 2007 to March 2009 and involved first year students and academics at the University of Northampton (general engineering), Loughborough University (electrical engineering and civil engineering) and the University of Birmingham (electrical engineering). A number of practising professional engineers from a range of industries (including lift manufacture, general manufacturing, motorsport, aerospace and electronics) were also interviewed. A breakdown of the location and number of interviews is shown in Figure 5.

Figure 5. Interview locations




The interviews were recorded and transcribed. Whilst most interviews were undertaken face-to-face, some involving academics and professional engineers were also undertaken by telephone. The overall length of audio data for all interviews is approximately 30 hours. Analysis is in the form of a phenomenographic study (Marton, 1981; Kvale, 1996; Sandberg, 1997; Vincent, Warren, 2001).

## Findings and reflection

### *Action research*

Feedback from the action research was obtained by several methods: the use of online tracking in the VLE, by online student questionnaires at the end of the autumn and spring terms, focus groups, classroom-based observation and as part of the parallel interview project.

Tracking showed that the VLE site had 688 student log-ins over the two terms and that of the 97 engineering students who had access to the site 65 (67%) had accessed the site at least once. The ten first year students who undertook the robot task accessed the site on a regular basis. Tracking of access to the RLOs showed that all had been accessed, although the tracking proved to be misleading due to the RLOs being also made available on a memory stick (for first year students) and as a weekly email to the whole engineering cohort. Tracking was also unreliable because of limitations of the SCORM implementation, discussed later.

Response rate to the online questionnaires was satisfactory, with 22 responses to the autumn, and 12 to the spring questionnaire. In the questionnaires and focus groups a high proportion of respondents believed that problem solving skills were vital or essential for engineers (99%), whilst a slightly smaller proportion believed that creativity was important (81%). Over 85% rated their problem solving skills as being improved by accessing the module content, while 64% believed that their creative thinking skills had improved. Over 94% regularly accessed the content on the site. 98% thought that a separate creative problem solving module was a good idea and 85% would recommend the RLOs on the site to other students. Of the students who also undertook the robot problem, 72% believed they were a good or excellent way for developing creative problem solving skills. 71% also preferred the RLOs to be delivered in a VLE rather than by email or memory stick. When asked if the module would be better as an online simulation with no hands-on practical robot activities only 25% responded that they would prefer this. The findings reported are comparable to those from the first cycle project.

Students were also asked what they found most and least useful about the module content and to make suggestions for improvements. Several students also commented that they wished this module had been available when they had started their BSc Engineering studies. Here are selected comments from the questionnaires and focus groups:

Most useful:

> "The methods you can use to solve problem and exploring different ways of getting to the right answer"
> "Taking the chance to be creative and solve problems"
> "Some of the files really helped me with problem solving in other modules on the BSc course such as creating oral presentations and writing reports etc."

Least useful:

> "I work full time so am unable to attend the classes as they are during working hours" [part time student]
> "Robot use because I am not in the first year"
> "This would be a lot more useful to students if they knew about it so it could be promoted better so that students are made aware of its useful content"

Suggestions for improvements:

> "More Lego robot projects and programming robots through different software"
> "More access to the robots"

The second cycle of action research involved the presentation of a number of skills in order to mediate the process of creative problem solving. A central student-generated problem was achieved using Lego Mindstorm NXT robots. Feedback through questionnaires and focus groups indicates overall satisfaction with the module. A high proportion of students also believed that the module had improved their creative problem solving skills in other subjects (although this is difficult to measure objectively).
It was observed that the Lego robots served to motivate students and generated a high level of intrinsic interest, capacities that were highlighted as lacking by the interviews. The use of a student-generated problem further promoted motivation and fostered a sense of ownership of the problem (again identified as lacking by the interviews). The robot activity also addressed a number of further issues that were identified both in the first cycle and interviews, including: the need for visualisation techniques when problem solving, the desire for realistic

experiential learning activities, the value of developing critical and reflective thinking skills, and the ability to work in teams.

When compared with the use of Java-programmed Lego RCX robots used in the first cycle, the use of Lego NXT robots along with the visual NXT-G programming software enabled students to quickly undertake much more complex tasks. This ensured that the focus for the module was creative problem solving rather than simply robotics.

Although students had continual access to the RLOs within the VLE, access to the robots was limited to a timetabled one-hour weekly session. Restricted access was also available outside this time, however several students suggested that additional access was required. An area for further investigation might be the use of a low-cost robot alternative that could be provided for students to take away. This would, however, rely on the student having access to a suitable computer, although this is not unfeasible.

The RLOs and the instructional design PBL model developed for the module proved a successful mechanism for delivery which could potentially be used to develop creative problem solving skills in different contexts or disciplines (i.e. the robot activities forming the ‘problem space’ could easily be substituted with a different activity). The RLOs were relatively easy to produce using the authoring software and to disseminate in different formats. It is also possible to re-purpose the content of the RLO itself using the authoring software. Several RLOs were successfully used to rapidly develop dedicated problem solving sessions using the robots for visiting school children and on a visit to a local primary school.

While it was possible to monitor access to each RLO, this was unreliable as the RLOs were also provided in untraceable formats (e.g. on a memory stick and by email). Problems were also encountered with the use of the SCORM object viewer within the VLE as this required a compatible web browser and version of Java in order to work correctly (not always installed on the student’s computer). What was evident from tracking, however, was that students who were not undertaking the robot activity were strategic in their access to the RLOs (e.g. RLOs relating to sustainability and ethics were accessed more when students were writing project proposals, whilst those relating to writing reports and oral presentations were accessed heavily when final year students were writing up and presenting their dissertations). One way of improving tracking might be by the inclusion of simple online tests built into the RLO which could be used to feed

back data to the VLE. A further enhancement of the RLOs would be the inclusion of audio and video as appropriate.
Whilst attendance on the module was voluntary, a regular cohort of first year students participated. The RLOs were also accessed by and proved useful to a large number of students in other years of study. Unsurprisingly, findings from the interviews indicate that the key motivation for students to do well with respect to developing (creative) problem solving skills in the academic environment is value and reward, either in the form of grades or enhancing employment opportunities. Whilst the module currently offers intrinsic reward (and some small gratuity in the form of a memory stick and task prizes) it does not presently offer academic credit. Whilst metrics (measuring creative problem solving ability) were considered, they were not investigated or implemented in the module (albeit simply using the number of tags collected in the robot task). This important area could form the basis for an entire project in itself. Academic accreditation of the module has been undertaken for the 2010/2011 academic year.

### *Interviews*

Analysis of the occurrence of particular concepts for each interview question, alongside re-analysis of the raw interview data has been used to form three outcome spaces. This has been undertaken using the software analysis tool Nvivo. The outcome spaces represent a composite of individual perceptions from each of the three groups of interviewees to the three fundamental interview questions, and the resulting categories within each outcome space represent the composite perceptions of each group (students, academics and professional engineers). Within each category basic ordering of the concepts has been undertaken which indicates the perceived relative importance of that concept. These are shown in Figures 6, 7 and 8, with each rectangle representing a concept.

Figure 6. Outcome space Q1- - good engineering problem solver

| Engineering Student | Engineering Academic | Professional Engineer |
|---|---|---|
| Applies Logic | Applies Logic | Applies Logic |
| Uses theoretical knowledge | Uses theoretical knowledge | Understands the problem |
| Undertakes research | Understands the problem | Applies practical knowledge and experience |
| Understands the problem | Has a process or strategy | Uses theoretical knowledge |
| Talks it over with other people | Undertakes research | Has a process or strategy |
| Is creative | Is confident | Talks it over with other people |
| Plans | Is creative | Uses memory of similar problems |
| Reflects and has an open mind | Synthesizes information | Reflects and has an open mind |
| | Reflects and has an open mind | Is creative |

Figure 7. Outcome space Q2 - creativity in engineering

| Engineering Student | Engineering Academic | Professional Engineer |
|---|---|---|
| Is a personal capacity | Is bounded | Is looking for improvements |
| Involves an open / free state of mind | Problem with definition | Is affected by environment |
| Problem with definition | Is a personal capacity | Is a personal capacity |
| Is bounded | Is looking for new ideas | Problem with definition |
| Is looking for improvements | Is looking for improvements | Is looking for new ideas |
| Is looking for new ideas | Is a spectrum of disciplines | Involves an open / free state of mind |
| Is “looking outside the box” | Involves ingenuity | Might be close to devious (patents) |
| | Has metrics | |

| Engineering Student | Engineering Academic | Professional Engineer |
|---|---|---|
| Practical activities | Real life problems | Real life problems |
| Groupwork | Groupwork | Groupwork |
| Project work | Having practice questions | Challenges |
| Having flexibility | Developing processes and methods | Involving theoretical / practical knowledge |
| Having practice questions | | Having motivating environment |

Figure 8. Outcome space Q3 - improving skills

It is not possible within the confines of this short paper to provide a detailed analysis of the outcome spaces or to provide the required supporting quotations. Considered here alongside each of the outcome spaces, however, is a summary of the key observations to each of the three interview questions.

Findings from Question 1 confirm previous studies in that students tended to identify discrete skills appropriate to stages of a typical problem solving process rather than taking an holistic process-based approach (Larkin et al., 1980a; Larkin et al., 1980b; Larkin et al., 1980c; Larkin et al., 1983). Students also tended to concentrate on analysing the problem and identifying what knowledge or skills they already had. Professionals, on the other hand, took a broader approach by considering the problem as a whole and selecting and adapting strategies accordingly. Also evident was the dominance of the application of logical thinking within engineering (McCaulley, 1976; McCaulley et al., 1983). This clearly demonstrates the need to develop activities and instruction that develop process skills and which also encourage creative thinking. It was also apparent that when a knowledge deficit was encountered in both students and professionals that an attempt was made to resolve this through research (information finding) or talking to other people. What is being observed here is the notion of knowledge networking, as suggested by Allen and Long (2009). For students to apply knowledge acquired this way effectively requires additional skills such as criticality, reasoning, synthesis and presentation. These skills are often not developed until much later in undergraduate studies (towards the dissertation), suggesting perhaps that these should be developed much sooner. It is the development of process-related and knowledge networking skills and activities to stimulate creative thinking that have been implemented in the action research.

In Question 2, looking at the perceptions of what creativity is in engineering, themes are largely convergent across students, academics and professionals, but with some exceptions. Two key perceptions relate to the actual use of the word *creative* within an engineering context and with the belief that being creative is a personal capacity (as highlighted by Abra,1997). Whilst it was not *disagreed* that there was a place for creativity within engineering, it was more often associated with artistic subjects such as music or art. Other associated (but probably more tangible) concepts such as innovation, ingenuity and entrepreneurship were offered as more suitable alternatives in many cases. It was also widely believed that creativity (and its associated concepts) was a personal, internalised capacity that not every person might be able to demonstrate or call upon. In nearly all cases, creativity was associated with some end product or artefact and seldom with the process that had been undergone to come to a solution. Creativity as a process of improvement, as opposed to devising something new, was the most important perception for the professional engineer. It is perhaps these tensions with creativity in an engineering context that need to be overcome with engineering students, and possibly in the engineering arena as a whole, something which the action research has attempted to achieve.

Question 3 asks for perceptions of what might be done in order to improve problem solving skills and encourage creative thinking in engineering undergraduates. Again, responses from both students and professionals were consistent and predictable in that both practical activities and the involvement of groupwork (or teamwork) were perceived as essential commodities for improving these skills, agreeing with the findings of Felder (1998). Whilst a whole range of practical activities were identified, ranging from project work and design tasks to case studies and industrial placements, the emphasis here was clearly on their applicability to real life. In addition, professional engineers identify the requirement for a stimulating and motivating environment. Indeed, it is suitable practical activities involving both groupwork and environment that have been taken forward into the activities within the action research part of this study.

## Conclusions and further work

Solving problems is what engineers do. Developing creative problem solving skills in engineering students is clearly of vital importance, as highlighted by the many benchmark and policy statements. Effective problem solving is more than simply being able to solve routine or familiar problems; it is also about recognising strategy and process.
This study has attempted to develop and foster creative problem solving process skills using a PBL-based instructional design model. RLOs have shown their potential for use as mediation tools within the model. Lego Mindstorm NXT robots, which have replaced the Lego RCX robots used in the first cycle, have proved an effective and stimulating means for generating and solving problems. Student feedback has, on the whole, been positive and many students believe that their creative problem solving skills have been improved.
Both the cycles of action research and the parallel interviews have highlighted a number of useful themes that have been, or will be, incorporated into the module. Themes for further work include:

- Investigation of the notion of the acquisition of knowledge through knowledge networking, and methods for its improvement
- Development and enhancement of the PBL model using RLOs, and investigation of its potential for use in other disciplines
- Development of further RLOs and enhancement of existing RLOs to include audio, video and online testing
- Investigation of alternative low-cost robots and practical activities in order to enhance accessibility
- Investigation and implementation of metrics in order to assess creative problem solving ability (which could form a whole project in itself).

Further details about this research work, along with the RLOs to download, can be found at:
http://www.northampton.ac.uk/info/200266/problem-solving-and-creativity-for-engineers

## Acknowledgements

The author would like to thank the students who participated in both cycles of this action research project. Thanks also go to the students, staff and professional engineers who took part in the interviews. The author acknowledges the help and materials made available from the Centre for Academic Practice at the University of Northampton.
Both cycles of Action Research for this project have kindly been funded by mini-project awards from the Higher Education Academy Engineering Subject Centre at Loughborough University.
The interviews have kindly been supported by a Teaching and Learning Enhancement Award (Fellowship) from the University of Northampton.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## Sintesi

*La creatività nella risoluzione di problemi è molto più importante del pedissequo uso di metodologie preesistenti nella risoluzione dei problemi ingegneristici, l'approccio creativo è ormai considerato una necessità sia per studenti di ingegneria sia per laureati, utilizzando in modo flessibile le conoscenze acquisite al fine di superare i problemi e le difficoltà.*
*Lo studio riportato in questo articolo si basa sull'utilizzo di oggetti didattici riutilizzabili all'interno di un ambiente virtuale didattico, per le tecniche di apprendimento sono stati usati robot della serie Lego Mindstorm NTX e il software NTX-G per la programmazione dei robot stessi. La risoluzione dei problemi è stata strutturata in un processo a cinque stadi:*
*1. Definire*
*2. Pensare*
*3. Pianificare*
*4. Eseguire il pianificato*
*5. Controllare il risultato*
*È stata pure elaborata una definizione ampia e condivisa degli oggetti didattici riutilizzabili che li considera entità, digitali o non digitali, che possono essere usate, riusate o referenziate durante l'apprendimento con supporto tecnologico. Tra gli ODR sono considerati i contenuti multimediali, i contenuti didattici, gli obiettivi di apprendimento, i software didattici e tutti gli strumenti software, ma anche le persone, organizzazioni o gli eventi usati come riferimento durante l'apprendimento con supporto tecnologico.*
*I robot sono stati utilizzati come metodo di incentivazione degli studenti per sviluppare abilità creative per la risoluzione dei problemi e parte fondamentale della prima delle due metodologie di ricerca applicate. Nella seconda sono state comprese le interviste a tre diversi campioni di soggetti, studenti di ingegneria, docenti e professionisti per*

*definire quali siano i parametri di giudizio per un buon risolutore di problemi, la creatività ed il miglioramento delle abilità di risoluzione.*

*Risolvere problemi è quello che un ingegnere deve fare. Sviluppare le abilità relative alla risoluzione creativa dei problemi è chiaramente di vitale importanza e si basa sul riconoscimento di strategie e processi.*

*Sviluppi futuri possono essere l'acquisizione di conoscenza attraverso reti di conoscenze e metodologie di miglioramento delle stesse, lo sviluppo ed il miglioramento di modelli di oggetti didattici riutilizzabili anche allo scopo di usare audio video e test online, ma soprattutto l'implementazione di una metrica per valutare la abilità di sviluppo di soluzioni creative.*