

# Action Research in Engineering Design Active Learning Project

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## Abstract

This project is an initiative at City University of Hong Kong to overcome a problem in one typical engineering classroom which might be described as 'the passive student syndrome'. This is characterised by poor student motivation, the utilisation of simple recall techniques to meet minimal module requirements and an over-reliance on the teacher to provide content and direction. All of these are typical features of surface learning. The investigator has sought to introduce first year students to aspects of the engineering design process as well as fundamental engineering concepts in ways which overcome student complaints of boredom often brought about by a 'too theoretical' approach. The introduction of 'fun' elements into certain components of the course has been used in an attempt to promote Active Learning, to combat low motivation and the exclusive use of surface learning approaches to meet its demands. The overall process adopted by the investigators is based on Action Research which progressively builds on previous planning and implementation in a systematic and reflective way. After two consecutive years, the action research has completed two cycles. The surveyed results have indicated that student motivation has increased, and a sense of enjoyment, ownership and achievement has been created. Furthermore, it has been identified that this kind of teaching method can improve the learning of engineering design subject matter significantly.

## Introduction

Higher education in Hong Kong has specific characteristics which give it its uniqueness. One set of such characteristics is the way in which students perceive the desirability of individual higher education institutions. Significantly, a definite hierarchy of institutions seems to exist affecting student first-choice preferences, i.e., it is perceived by students to be more desirable to study at Institution A as opposed to Institution B. Moreover, a second hierarchy also exists as to the particular disciplines students chose to study. In general, the first of these hierarchies remains relatively stable over time, however, the second changes depending on various social, political and economic factors. While there are obviously exceptions, at any one given time secondary school graduates will compete keenly for entry to Discipline X in Institution A. If they are unsuccessful in this first choice they then opt for Discipline Y in Institution A. Consequently, many discipline areas find that their first year intakes contain significant numbers of students who do not necessarily understand the discipline they have enrolled in nor have a great commitment to that discipline.

A second set of characteristics adding to the particular nature of higher education in Hong Kong has to do with the prior learning experiences students bring with them to the institution. As in other parts of the world, higher education students in Hong Kong bring to the learning situation particular motives and conceptions of learning which influence the approaches to study they employ during their tertiary education to achieve their academic/professional goals. These approaches to study are also a result of their previous learning experiences during their secondary education. In Hong Kong the anecdotal experience of lecturers and recent research

(Biggs, 1992; Gow and Kember, 1990) suggest that the approaches to study employed by first year students may be termed 'surface'; approaches which have often been described as barriers to the successful achievement of some commonly held, higher education goals (Biggs, 1989). Indeed, the anecdotal experiences of lecturers was not the only source of concern in this matter. Early Hong Kong Education Commission Reports expressed concern over the narrow range of teaching strategies employed by secondary school teachers resulting in students being exposed to restricted learning experiences. As a consequence of this, it was felt that many secondary school graduates were entering universities and colleges poorly equipped with what may be termed desirable study skills for higher education — skills which would generally help the students progress from dependent to independent learners. Undoubtedly, many Hong Kong higher education teachers have found, among other things, a large number of their first year students to be overly teacher dependent and reliant on strategies by which they essentially segmentalise content knowledge and memorise it. A specific example of such a situation has occurred at City University of Hong Kong, where lecturers concerned with teaching students enrolled in a first year Engineering Design and Analysis module within the Department of Manufacturing Engineering have observed that:

- the recent secondary school experience of their first year students has encouraged them (the students) to develop and practice skills for accumulating or taking in knowledge; and
- these same school experiences have done little to encourage or develop within the students any skills as to how this accumulated content knowledge might be applied in practical, problem-solving situations apart from the most unsophisticated 'formula application' way.

These students were observed to be comfortable working within a learning context where they were able to depend on the lecturers providing them with the necessary information and direction as to how to complete problem-solving exercises. Furthermore, the lecturers also found that many of these students had little or no understanding as to exactly what was entailed or expected of them during an engineering and design course. This particular concern was brought about because the lecturers teaching this module were fully aware of the demands that would be made on the students during the final year of the programme. At that time the students would be expected to complete major problem-solving projects which would account for a significant part of the total assessment for the whole course.

Such a scenario is common throughout Hong Kong's Higher Education Institutions. Many academics are engaged in an almost continuous search for ways in which to develop and further enhance the skills and understandings students will have to utilise in final year projects which insist on the application of knowledge and skills to new problem-solving situations.

The authors searched for a feasible way of improving this particular aspect of student learning. They perceived their problem as characterised by a lack of the appropriate skills to successfully undertake independent learning; an absence of commitment/motivation to the discipline; and an ignorance of the links that exist between theory and practice within the design process. What was needed was a solution which:

- helped develop within the students a sensitivity towards the design process in engineering contexts;
- provided early experience/training in those skills essential to the successful completion of the final year project; and
- encouraged an awareness in the students of the links that exist between theory and practice in the sense that students must recognise the need to provide more than a 'head solution' to any given problem. There is a need to actually construct a solution and test to see the extent to which it is successful.

The authors accepted that the particular requirements they were searching for in the solution to this problem were best met, in general, by the claims of active learning.

## **Active Learning: A Framework for a Possible Solution**

In large part it is true that higher education teachers rely more on intuitive understandings of active learning than on any commonly accepted definitions of the concept. However, the authors supported the contention that active learning requires students to

do more than just listen. They must read, write, discuss, or be engaged in solving problems. Most important, to be actively involved, students must engage in such higher order thinking tasks as analysis, synthesis, and evaluation. Within this context, it is proposed that strategies promoting active learning be defined as instructional activities involving students in doing things and thinking about what they are doing.

(Bonwell and Eison, 1991, p. iii)

In the United Kingdom developmental work focusing on improving student learning accepts that active learning positively affects student learning. Two particular aspects of the student learning research literature, experiential learning and learning in groups, have been identified by Entwistle, Thompson and Tait (1992) as constituting active learning's strongest roots in that literature. Experiential learning is based on the notion of developing an understanding of any particular subject matter through a process of reflecting on the personal experience gained by interacting with that subject matter. Its advocates (e.g., Kolb, 1983) that by encouraging students to consider the ways in which their understanding of particular concepts/subject matter changes as a result of reflecting on the consequences of related experiences adds a dimension of relevance to their learning.

Similarly, group learning situations promote active learning by providing a context within which students are able to work collaboratively with their peers. Studies (e.g., Harri-Augstein and Thomas, 1991) indicate that by having opportunities to discuss ideas/issues with peers contributes positively to students enhancing their understanding of a particular topic. However, the notion of using collaborative groups to enhance student understanding may be developed well beyond simply discussing ideas with peers. Collaborative groups should be structured to provide students with contexts within which they set and solve relevant problems.

The emphasis of problem-based approaches is on learning processes of enquiry which proceed by asking what needs to be known to address and improve a particular situation. This is quite different from some of the garbled versions of discovery learning which imply that students are supposed to invent knowledge which is already known. The knowledge which students use needs to be identified and applied in the context of the present situation.

(Boud and Feletti, 1991, p. 22)

The relevant literature dealing with problem-based approaches emphasises that they are more than simple ways of teaching — they are ways of learning. Viewed as such, the concept assumes that a particular learning environment is created and structured so as to ensure that knowledge learned is applied, tested and modified in a problem solving context and learning is constantly enhanced.

## Student Centred Activity — Active Learning CityU Style

The Manufacturing Engineering & Engineering Management Department of City University of Hong Kong traditionally has encouraged Active Learning among students. This is reflected in the planning of the undergraduate courses where Student Centred Activity (SCA) is included in each academic year to facilitate student learning. The SCA usually takes the form of a small group (4-5 students) collaborative project aimed at solving a given engineering problem. In the first year of the Manufacturing Engineering or Mechatronic Engineering course at least 30 hours are devoted to carrying out the SCA. The aim is to encourage students to apply the principles covered in the course by analysing and designing a piece of mechanical equipment or an accessory. In the beginning, the SCA focused on what may be called 'hard core' engineering-type projects, eg., the mechanical design and analysis of a centre lathe gear box. The feedback from the students after the project indicated a definite lack of enthusiasm.

### Bringing 'Fun' Into the SCA's

It is well accepted that student learning is affected by a large number of factors, such as student and teacher characteristics; institutional characteristics and culture; learning climate and environment; teaching processes; course design such as content, organisation and methods of teaching; student approaches to learning; and assessment and evaluation approach and practices (Balla and Boyle, 1993). Previous sections have indicated first year students entering this particular course are usually passive, dependent learners. A few years ago, on assuming responsibility for the SCA component of the course, one of the authors determined to influence student motivation and approaches to learning by varying the nature and demands of the SCA. This was to be done by a gradual process reflecting student behaviour and feedback.

The first year simply repeated what had been done previously — the SCA required the students to analyse and design an engineering project of their own choice. The project was purely paper based and included library search, component analysis, presentation and report writing. The result was not satisfactory due to a combination of the following reasons:

- The students were not entirely interested in doing the engineering course they enrolled in as mentioned.
- The students were not interested in doing 'head only' type of projects.
- There is a stigma to engineering design because it is traditionally thought of as boring.

These results were disappointing though understandable given previous experience. The authors were convinced that the SCA's were inherently well suited to encourage students' active learning, however, there appeared to be some problems with the environment — the setting for doing the project was 'too serious' for first year undergraduates to the point that they did not enjoy their learning. Experience from other countries indicates that positive outcomes for projects such as this can be increased where a fun element is introduced. It was then decided that **fun** and **action** elements were to be included into the SCA in the second run. As a result, in the second run, the students were asked to do two group projects. On the safe side, one of the projects was again purely paper based — to design a loadcell according to set specification. The second project was to **design** and **build** a working projectile machine. Projects of the second type require a lot of technical support from the engineering workshop and the first year students have little experience in manufacturing things. It was just like walking on a tight rope. To encourage students to participate fully and to increase the fun element of the SCA a competitive component was also introduced into the project. The result this time were gratifying. Feedback responses indicated students displayed a sense of ownership which was accompanied by enhanced motivation. Most groups worked hard on projects which they accepted as their own 'baby'. A sense of achievement

in engineering design was also developed in most students because this was the first time they had designed and made something that could stand a test. Engineering can be fun!

## **Action Learning Research on SCA**

The authors have been able to receive a grant to carry out Action Learning Research on the SCA. The aims were to measure the changes in student learning attitudes due to such teaching environment. The research activities were conducted for two cycles and it was one year between two consecutive cycles. The preliminary findings had been reported in the ALP interim report (1996). In brief, the data collected in the preliminary studies have confirmed that the SCA was successful in improving the students in learning engineering design. The majority of the students had expressed confidence in the subject after finishing the project. However, the instrument for measuring pre- and post-SCA student attitudes needed refinement. The effect of group work on learning would be an essential item on which the following research would focus.

### **The Second Cycle**

In the second cycle, the SCA was to design and implement a mechanism which would control the fall of a 1kg mass through a height of 1m. The mechanism should be able to utilise the energy provided by the falling mass to push a toy car to travel for a specified distance up to 10m on a flat concrete floor. Furthermore, a simple piece of software was required to predict the performance of the system accurately. The SCA assessment was divided into four major areas:

- 1 Project achievement — to test whether the car will stop at the required position using parameters calculated from the accompanied software.
- 2 Design and analysis — to consider the design, creativity and application of engineering knowledge, etc.
- 3 Project report — to look for organisation of material, clarity, programming and so on.
- 4 Presentation — quality, style and clarity.

At the end of the project, students were also asked to conduct peer assessment which aimed to rate individual students regarding their own contributions to the SCA. As in the last SCA, a competition was organised among outstanding groups.

As far as measurements were concerned, both questionnaires and interviews were used to find out the learning experience and attitude of the students through the SCA.

### **Questionnaire**

A new questionnaire using a 5 point scale was designed which had 3 questions on the subject learning; 9 questions on the SCA learning experience and 14 questions on the matter of group work. It was obvious that a lot of attention was given to the group work issue. The same questionnaire was administered in the third week (132 replies) and at the end of the SCA (125 replies). The comparison between the pre- and post-SCA are discussed as below.

#### ***Subject Matter Learning***

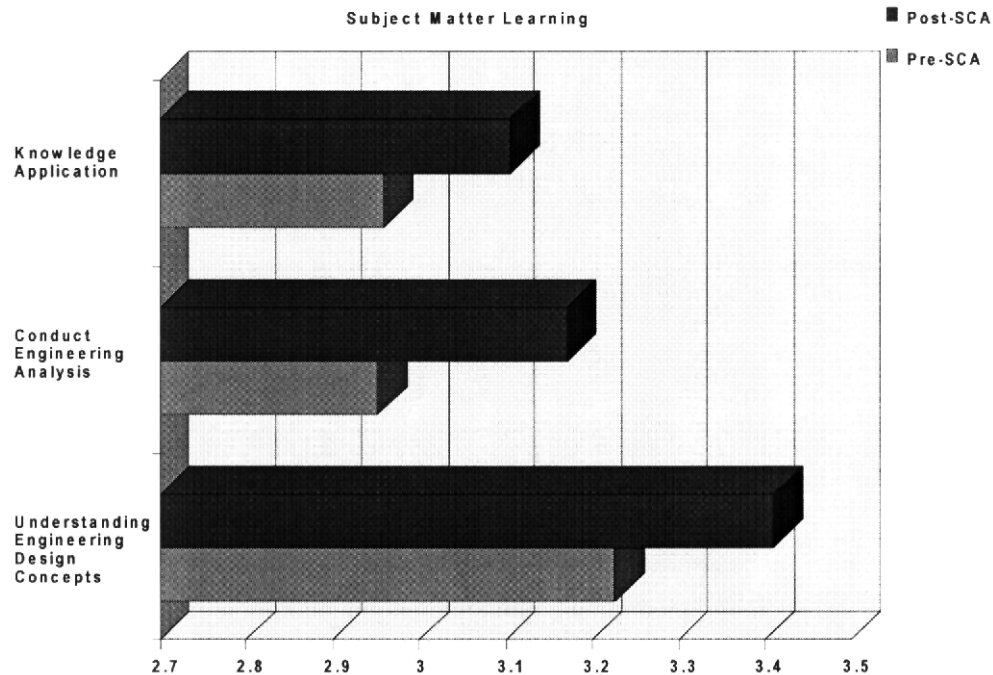
Concerning learning of the subject matter, the students were asked:

- whether they understand the concepts of engineering analysis;
- whether they know how to conduct engineering analysis; and

- whether they know how to apply the knowledge learnt.

Figure 1 shows the change in student learning. The improvements in the three aspects are unanimous. Only the mean score is used for pre- and post- comparison; the improvements are 0.18, 0.22 and 0.15 respectively.

Figure 1: Subject Matter Learning



### Learning Experience

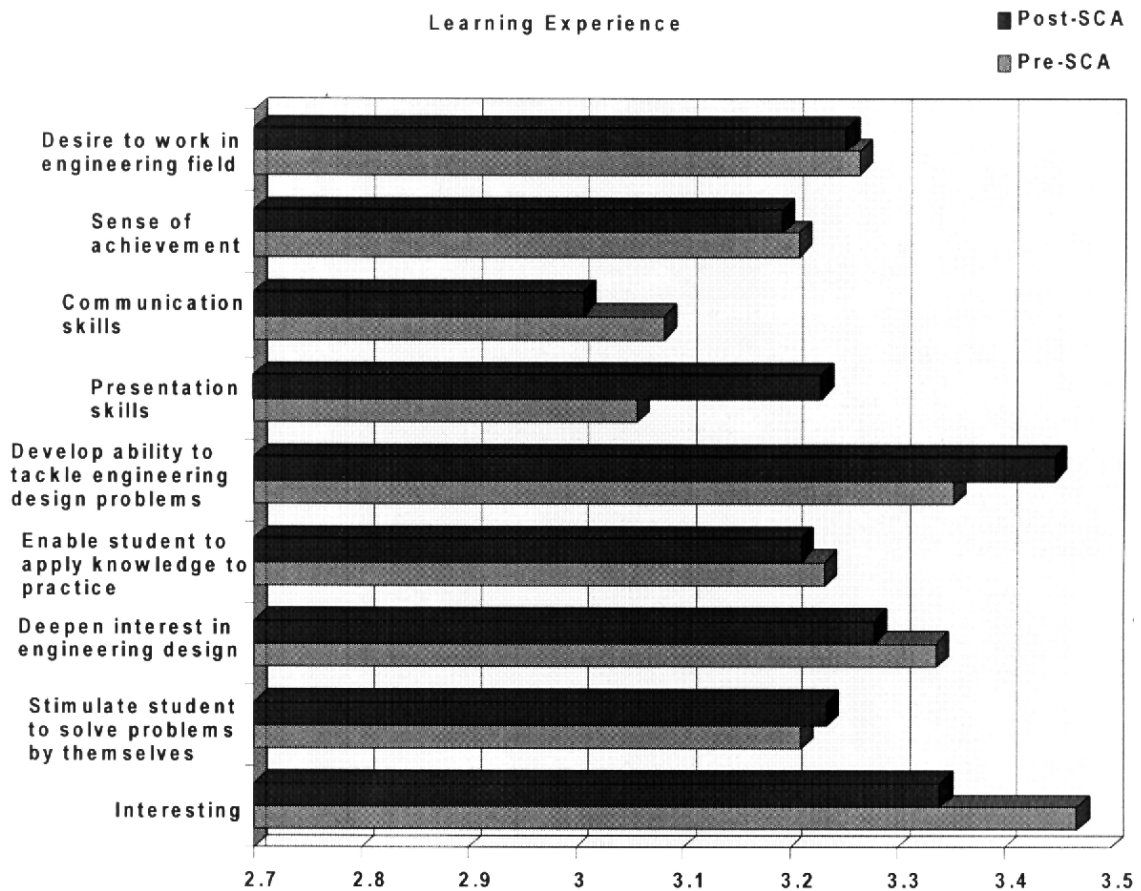
This aspect is measured using the next nine questions. Of the changes obtained, 5 out of 9 are only marginal ( $<0.07$ ) and are not discussed here.

Referring to Figure 2, there is a  $-0.13$  change in when the students were asked about whether the SCA was interesting. This question might be due to the fact that the project was a second run of the same kind and the students were less excited about the outcome. In fact, this opinion was also raised in subsequent interviews.

Two questions which concerned the ability to tackle practical problems in engineering design and presentation skills have a positive change,  $0.10$  and  $0.17$  respectively.

However, the question which probed communication skill development has a change of  $-0.07$ . This negative score may reflect the fact that students experienced difficulties when working together. This is further explored in the next section.

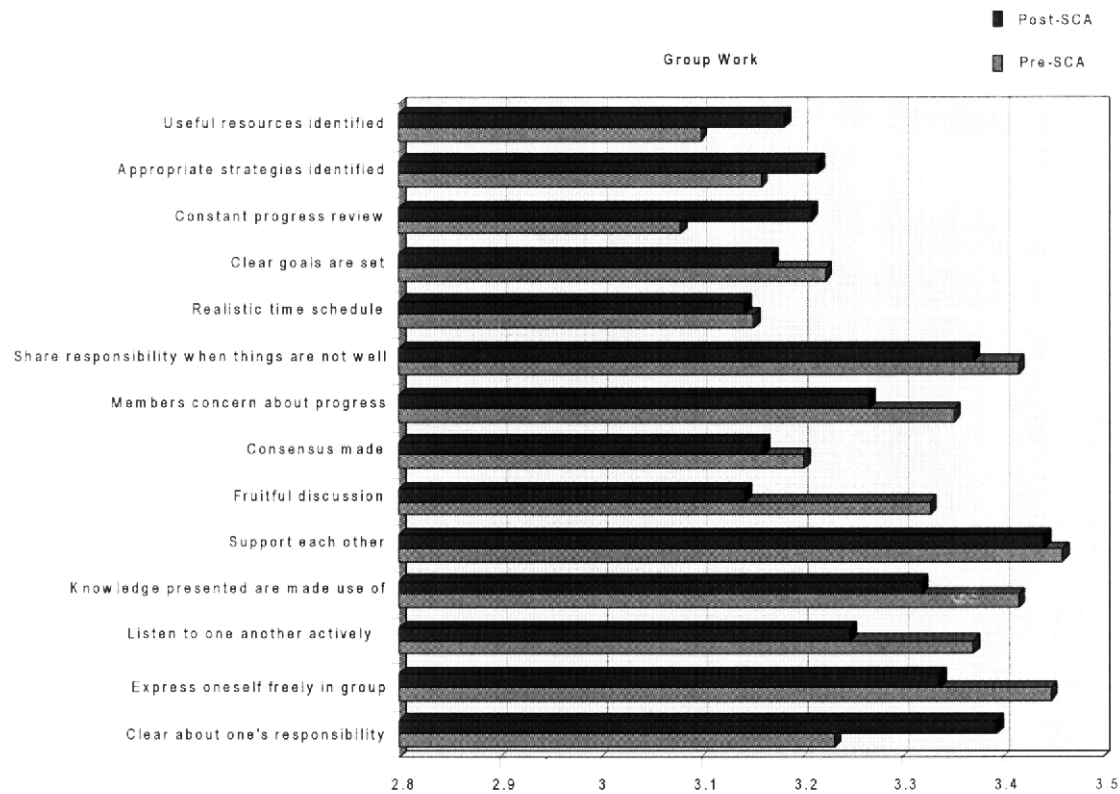
Figure 2: SCA learning experience



### Group Work

The result regarding the change in attitude towards working in groups is different from the previous two aspects. Out of the 14 questions, 5 have scored a significant negative change, only 3 scored a positive change and the rest only show a marginal difference ( $<0.07$ ). The results for comparing group work experience between the post- and pre-SCA are shown in Figure 3. After examining the questions which scored significant negative results, it is apparent that communication within the group is the major problematic issue the students have encountered during the project. This is further confirmed by the interview results from the next section.

Figure 3: Group work



The significant changes are tabulated in the following table.

Questions	Change
Everyone is clear about his/her responsibility.	0.16
There was constant review of progress.	0.13
Useful resources were identified.	0.08
Everyone could express himself/herself freely in the group.	-0.11
Members listened actively and heard one another.	-0.12
The knowledge and experience present in the group were made good use of.	-0.10
Discussion were fruitful and effective.	-0.18
Members were concerned about how the group was doing as well as what was being done.	-0.09

### Interviews

In order to tap into aspects which the questionnaire was not able to probe, interviews with student groups were conducted. A total of 28 students (from 6 projects groups) were selected



randomly and were interviewed near the end of the project. Each interview lasted for one hour and was chaired by a research assistant who also transcribed the recorded section. The students were asked to comment on the three aspects which were:

- learning experience;
- the SCA; and
- on group work.

It should be noted that these aspects were also covered in the questionnaire. In each aspect, there are three questions.

### ***Learning the Subject Matter***

- Q1. What do you think about the SCA experience?** — Most of the comments were positive. Students used phrases like fun, happy, fresh, free, precious and special to describe their learning experience. Furthermore, they said, 'I can design and create anything'; 'I have a great sense of achievement'; 'I have learnt'; 'I can apply mechanical theories'; 'It is precious to be able to work with others'. They also commented, 'There are sad moments as well as happy moments'; 'Happiness is more than sadness'; 'It is hard labour work'; 'To produce the best product within a bad situation (e.g., insufficient materials)'.
- Q2. What have you learnt during the SCA?** — The responses to this questions were sparse. However, majority of the interviewees mentioned the following: 'how to work with others'; 'the group must be cooperative in order to solve problems'; 'to work and be productive within constrains'; 'how to design and handle a project'; 'there is gap between theory and practice'.
- Q3. Now the SCA is completed, what do you think about Engineering Design?** — Most students have commented that: 'engineering design needs steps and procedures just like constructing a jigsaw puzzle'; 'a lot of factors such as production, price, safety, etc. must be considered during the design process'; 'there is difference between theory and practices and there are a lot of unpredictable things which cannot be handled using theory alone.' The students also mentioned the project is interesting, requires experience, is easier said than done, requires a lot of thinking and so on.

### ***The SCA***

- Q1. Looking back, do you have any strength and weakness during the SCA? How can you improve your weakness?** — Regarding strength, most students agreed that good cooperation, positive involvement and sharing of knowledge and ideas gave them the winning edge. However, the lack of cooperation, lack of division of labour and initiatives were large obstacles. Furthermore, they also said that time management and weak project planning were the major pitfalls during the SCA.
- Q2. What are the difficulties you have come across during the SCA?** — Unanimously, most students commented the lack of resources and suitable tool for making the prototype were the main difficulties they have encountered.
- Q3. Any comments on SCA? Any future improvements on SCA?** — The responses to this question were very diverse. With respect to the response to Q2, the issues on resources and equipment were the most requested improvements. In addition, the students said more working space and time was required for the SCA and preferred more advice from the tutor if possible. Last, they commented that concept and spirit of the SCA was good.

### **On Group Work**

- Q1. From your SCA experience, what advantages do you think group work can impart on learning?** — The majority of responses considered that group work had positive effects on their learning, such as learning faster, learning more, easy absorption of subject material, time saving, being able to learn from others and so on. However, a few students mentioned that group work had no bearing on the relationship to learning.
- Q2. How is the cooperation of your project group? Did you encounter any problems concerning working together during the SCA? If there was some, how did you solve the problems?** — Among the six groups, five considered their cooperation from average to excellent. One group said they had a comparatively bad start, however, the situation was much improved later. As far as group work problems were concerned, they talked about communication problems and that one person might do all the work. In order to solve the group problem, the students said better communication/discussion and voting would help.
- Q3. Do you consider your group was successful in working as a group? What are the main ingredients which will lead to success in group work?** — All the responses considered their groups to be successful to different degrees except that one student commented his group work was only acceptable. When asked about the criteria for success, the responses were: devotion, being serious about the project, giving, cooperation, helping each other, having a goal, to score marks, pressure, accepting other people's weakness and being punctual. On the other hand, the main reason for lack of success was the lack of communication.

### **Summary**

After two consecutive Action Learning Research cycles were carried out on the SCA, it was confirmed that the SCA had enhanced students' learning of the Engineering Design subject. Moreover, the learning experience provided by the SCA was generally positive. As far as group work was concerned, it was apparent that the first year engineering students could not naturally work with other people in terms of projects. They mentioned that communication problems were the main obstacles during the SCA. This was also reflected in the questionnaire response, the item concerning communication skills development had a negative change of -0.07. However, most of the group commented that their group work was successful and they overcame the difficulties they encountered in the beginning. From the interviewing sections, the students also identified crucial factors for success group work. Therefore, it can be said that the SCA serves the purpose as a first step to train the students to work in groups with which they had no experience before, although the results from the questionnaire showed the SCA otherwise. Furthermore, as a reflection on the project, it shows that student skills such as group work, negotiating and assertiveness, problem solving skills and so on are very important in motivating students and improving their performance. However, with increasing pressure on class contact time, staff need resources to support the skills development of their students.