DEVELOPMENT OF PROCESS COMPETENCIES BY REFLECTION, EXPERIMENTATION AND CREATIVITY

Anette Kolmos and Lise Kofoed

Aalborg University, Denmark

Abstract: Development of process competencies has become a core part of lifelong learning and a social requirement to universities. However, teaching and learning process skills is not an easy task as they are not purely analytical, technical, or scientific abilities but rather the individual's personal approach to learning, creativity, co-operation, communication, independent work, behavioural changes, self-management and self-evaluation as well as handling their theoretical and professional knowledge in different situations. They represent a meta-cognitive level of both action and knowledge. They represent a form of knowledge in action, which may be tacit, and at the same time explicit.

At the Faculty of Engineering and Science at Aalborg University, process competencies are an important part of the problem based and project organised engineering curriculum, because co-operation, project management, and communication are recognised as core skills in engineering work. Also because they are an implicit and necessary objective in a Problem-based Learning (PBL) curriculum; however, practising a PBL curriculum does not secure development of these skills. Studies indicate that assimilation of these personal competencies is restricted to a tacit level if the process in the groups does not reflect them (Kolmos, 1999).

This lecture will address methods for learning process competencies and especially how to emphasise creativity and personal innovation. During the first year program at Aalborg University students have to submit a group-based portfolio, which is introduced through a course, that incorporates co-operation, learning, and project management. The theoretical frame for that work is based on the Kolb circle (Kolb, 1984), and the methods of reflection and experimentation have been differentiated at three levels: 1) common sense, 2) horizontal comparison and 3) vertical conceptualisation. This differentiation is made for several reasons, but not at least in order to stimulate creativity and to facilitate the implementation of the creative ideas. Those aspects can be stimulated much more by emphasis on the experiment as a learning method.

1. INTRODUCTION

Knowledge society demands development of new competencies in a lifelong learning perspective. We know very little, about which demands knowledge society will make for educational objectives and competencies in higher education. But the development of lifelong learning means among other things that the learner is able to learn and renew his/her knowledge, and last but not least relate his/her knowledge to the knowledge of others and other fields of knowledge. So it is an indirect demand that the individual is able to facilitate his/her own knowledge creation in a given social context.

When we talk about process competencies it includes, on a concrete level, learning to learn, creativity, co-operation, communication, independent work, behavioural changes, self-management and self-evaluation. But when we choose the concept of competencies, it also indicates that on a general level we are talking about the individual's potential capabilities. Ellström's concept of competencies (Ellström, 1997) covers cognitive (typical subject area qualifications and skills), affective (motivation and emotion), psychomotor skills, personal factors (self-perception and self-worth) as well as social factors (co-operation, communication, and management). All these elements are part of the competency concept and they have to be regarded as an integrated process. They represent the potential for personal development (Kofoed and Kolmos, 2001).

Considered a little more pragmatically process competencies cover more or less the same as transferable skills, generic skills, higher order skills, metacognitive skills etc. However, we prefer the concept of competencies because it indicates the potential capabilities, and we prefer the process term in order to stress that these competencies cannot be transferred from one area to another. One of the most important aspects is that the individual can learn from previous experiences and adjust previous learning to new situations.

Learning these skills cannot just be achieved by organising the students' learning environment and letting the student's practice. Learning these skills requires a more continuous reflection over practice to avoid that the learning ends up as tacit learning and tacit knowledge (Kolmos, 1999).

In a problem based and project-organised curriculum, process competencies are essential - otherwise the students are not able to practice these study methods. We have more than 25 years of experiences teaching these competencies at the first year programme at Faculty of Engineering and Science. During these years, this teaching has undergone major changes from running courses of instruction to students to a much more experience based learning approach (Kofoed and Kolmos, 2001). In the latest development of the course, called Co-operation, Learning and Project Management (CLP), the portfolio model was implemented based on the students' reflection on their own practice and experiments.

There has been no doubt that these courses would have to be based on an experience-based pedagogy, as the process competencies are in fact an integrated part of the individual's world of experiences - and it is the only way to learn it. The question really was how we could get the experience-based competencies transformed into innovation and creativity. Learning based on experiences runs the risk that perhaps it is difficult to set the stage for innovation, creativity, and new ways of thinking. The risk is furthermore that the students will need a common language for analysing, systematising and further development in the group.

By using the portfolio model, the students gather documentation regarding their own project and learning process along the way. They can choose themselves, how they will organise the work with the process analysis – a great deal of good advice is given in the courses – but the most critical feature is that they reflect and experiment and gather documentation of their experiences. These experiments and reflections constitute the foundation of a final reflection on the learning process, at which point the students would write their process analyses – which also could be referred to as their "public portfolio" (Black et al, 1994; Kjær Andreasen & Kolmos, 1999). This public portfolio or process analysis is part of their project and one of the criteria at the final examination.

Process analyses have developed a lot during this period, from being 2-3 pages written by random persons in a group, to real analyses of the development and the development potential in co-operation patterns and learning processes in the project groups. But still we are not quite satisfied. The theoretical background of the teaching methods are to a large extent based on Kolb (1984), Schön (1983, 1987) and Cowan (1998) - and thus we had a model where focus was on reflection as the learning strategy of the courses. At the same time the students were invited to experiment with the tools and methods presented to them during the courses. Experiments were made – but to less extent and not as well planned as we could wish for – which is among other things due to experiments being outweighed by reflections. Generally, the teachers' facilitated questions rather encourage the students to reflect on their learning

processes than to make experiments.

The problem is not that we are not conscious of the experiment – but on the theoretical methodical level we have worked much more with developing methods of reflection without linking these methods to corresponding experimental methods. In the very experiment is creativity, which is an important process competency for engineers. The role of the engineer is always to be innovative – to think ahead – and not only look back on former practice. There is a risk that the students will look back, if the supervisors do not attach the same importance to experiments and treat them the same way as reflections.

In this article we will therefore not only argue that the experiment is an equally important part of a learning strategy as reflection, but also point to various types of methods for understanding and planning experiments as a part of the learning strategy.

2. REFLECTION AS LEARNING METHOD

Our theoretical understanding of reflection is based on Cowan (1998), Schön (1983, 1987) and Kolb (1984). Cowan (1998) builds on Schön and Kolb and has developed the idea of deeper reflection loops. Basically, relatively minor "in"-reflection like Schön's approach to reflection takes place the whole time, but it is necessary from time to time to stop and conduct a more thorough "on"-reflection, more like a "Kolbian" reflection. For the development of the CLP-course, we used this theory for a period where we after each semester conducted reflection loops where the students had to reflect on their experiences during the whole semester. The problem was that the students could not remember what they had been doing. So while the theory was very attractive in principle – the problem was that in practice, minor reflection loops diminish to nothing and the larger loops became some kind of "common-sense", if the reflection process was not facilitated by experts and/or was occurring in a reflection-supported culture.

So our next theoretical step within the CLP-course was to take a closer look at the reflection part. Jennifer Moon (1999) defines reflection as "a form of mental processing with a purpose and/or an anticipated outcome that is applied to relatively complicated or unstructured ideas for which there is not an obvious solution". This is a relatively broad definition, which is not very precise so with inspiration from Schön (1983) we will add that reflection is covering the relation between our actions and their consequences, so that we relate the concept of reflection to action.

In the "Kolbian" universe (1984), reflection is an element in the experience-based learning process proposed by Kolb (1984), and a mean to get from experience to conceptualisation. It is a rational, distanced, and observed reflection in relation to the experiences and much more systematic compared to the reflection-in-action process. Reflection is a necessary link for a student to be able to develop his/her own concepts and abstract generalisations – and from these, to set the stage for new active experimentation. This description represents the logical progression with the "Kolb Circle".

Learning is chaotic - and does not always occur the way Kolb describe it. As teachers we experienced very soon that the Kolb-circle was not enough as theoretical foundation for the learning of process competencies. Difficulties occurred especially when the students had to take the move from reflection to conceptualisation - they thought this was somehow boring.

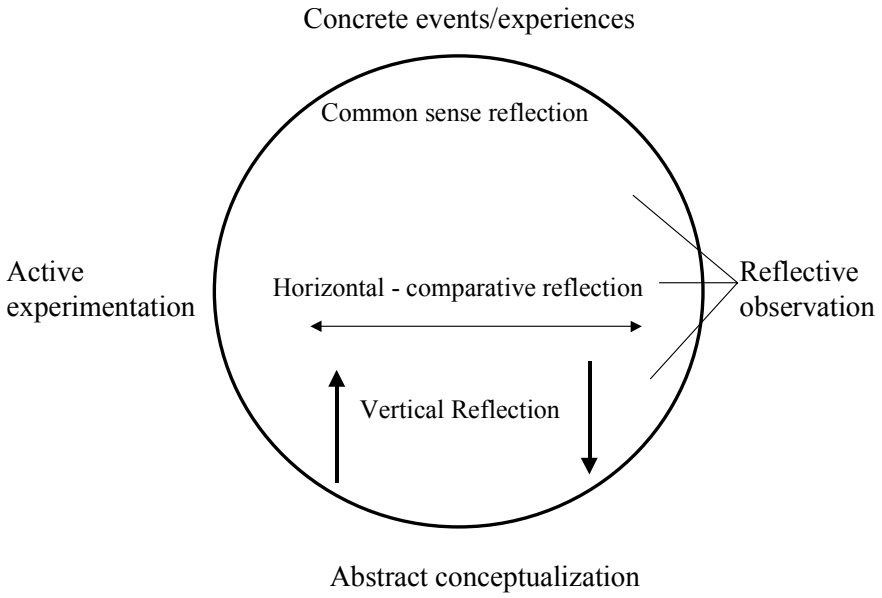

Figure 1. Levels of reflection and experimentation in the Kolb-circle

They wanted much more to use their experiences for setting up new experiments. So we started to rethink our approach to reflection and the methods we were using.

We differentiated reflection on three levels. As described in figure 1, we operate with three levels of reflection. On the common sense level, it is a question of attention - that the learner makes his first reflection-in-practice. The attention can be feelings/emotions and can be the documentation for what is going on.

The second level we call horizontal comparative reflection, where learning occurs through variation and comparison of experiences. Therefore, the analysis of various types of events and experiences will contribute to reach clarity – it is through the contrasts and dualism that the particular characteristics emerge. For example, it is only through the intensifying colour contrasts of a deepening red that the colour red itself can be sensed. The staging of new experiments is critical in the development of innovative processes. Otherwise, the building of experiences continues within a familiar framework of experiences. Peer reflection is a significant method, in which an environment for comparing experiences is established, in order to provide the opportunity for reciprocal reflection of comparable experiences.

The third level indicates that the learner has been able to go from reflection to conceptualisation and has created his/her own concepts and understanding. We have called this kind of reflection for vertical reflection. It is the cognitive process of induction based on contrasts that takes place with the purpose of gaining conceptual understanding and for concept creation.

These three levels of reflection have been a method to progress the learning in the CLP-

course. When the students start - the students can reflect on a common sense level - so the first step to learn how to work in groups is to create experiences. After the first semester the students can compare some experiences - but they are not able to generalise and conceptualise. At the end of the second semester some of the students are able to carry out vertical reflection - but the majority now manage the common sense and the horizontal reflection and have some ideas about the vertical reflection.

3. EXPERIMENT AS LEARNING METHOD

In the CLP course most of our questions are facilitating reflections at different levels and even if we are asking the students to experiment they are not doing it. So we have started to rethink reflection and experimentation once more.

Using experiments as a learning method has a lot of advantages:

- It is a conscious setting of the process where the students have to define objective, methods, outcomes etc. It offers the possibility of gaining awareness of action.
- It is a method for creating innovative experiences - to provide the opportunity for setting the stage for creativity, new thinking, and innovation.
- It fits very well with the learning style among engineering students, which is much more active than passive and most of the engineering students have an accommodating or converging learning style.
- Experimentation is a traditional way of defining learning and innovation among engineers.

However, it is very important to stress the point that the types of experiments we are thinking of are very different from the traditional scientific approach to experiments as e.g. controlled experiments. The controlled experiment is associated with objectivity, distance to the object, and limited focus in order to control and achieve an overview of what is going on. The experiments we are thinking of are linked to practice where it is very hard to limit areas for control - so it is not a question of achieving new knowledge - it is a question of trying out different strategies, activities as solution to the problem that has to be solved (Kofoed et al, 2001).

This understanding of the experiment is very much in line with Schön's understanding (Schön, 1983). Schön (1983:145) says:

> *In the most generic sense, the experiment is to act in order to see what the action leads to. The most fundamental experimental question is, "What if?"*

The question “what if?” emphasises exactly the difference between asking questions related to reflection and questions related to action. Questions related to reflection are normally “what have you done within this field, what did it lead to – and what have you learned from it?” If instead the question “what if?” is asked, the experiment and the action becomes the starting point, and all former experiences will not have to be added up at first.

Schön defines experiment at three levels: the explorative experiment, move-testing experiment and hypothesis testing. All three types of experiments take place at the same time, so the experimenter jumps from one to the other. But the three types of experimental methods have very different characteristics.

The explorative experiment is "when action is undertaken only to see what follows, without accompanying predictions or expectations (Schön, 1983:145). Using this kind of method can be very tacit - that the experimenter is just doing it - without having a clear oral formulation of what is going on - the action may lead to something - maybe to nothing."

Move-testing implies that there is an intention - an intended consequence of the action, e.g. we do this and this in the group in order to get to know each other better - or in order to establish a better social environment.

Finally, the third kind of experiment, hypothesis testing is much more like a traditional experiment with formulated and more complex hypothesis consisting of different variables. Compared to move testing the hypothesis testing is much more complex at a much higher analytical level.

These three types of experiments correspond to the three types of reflection. The explorative experiment corresponds well to a kind of common sense reflection, where the primary purpose is to test – to call attention. In the same way move-testing with its intended action is a question of testing/gaining experiences – "we did not manage to improve our co-operation, what did I do last time we succeeded – what can I do now?". Hypothesis testing also demands a generalisation of experiences and conceptualisation, because much more complex analyses of the experiences are necessary before new actions can be initiated.

But can reflection and experiment take place at the same time? – Yes it can, in Schön's opinion. He differentiates reflection-in-action from reflection-on-action, which are two types of reflection at different stages in the process. The reflection-in-action is based on experiment and reflection taking place at the same time – while the reflection-on-action is a type of distanced reflection, which we find in Kolb's approach. Just like the experimenter jumps from one type of experiment to the other – so does the experimenter jump from sometimes experimenting and reflecting at the same time – and to making pure reflection after stopping the action.

Creativity seen as idea production is closely connected to the explorative experiment and move testing, as actions can be initiated on the basis of intuition and not formal logical arguments. Therefore, it is important to plan the explorative experiment and move-testing as the basis of the students' learning processes – it is among others through testing one's own ideas and through processes run by the participants that motivation for learning is created and developed. But it is also important to slowly introduce demands of hypothesis testing – the point is that the profundity of learning is connected to various types of reflections and experiments.

There is a more complicated connection between the three levels and the profundity of learning. It is not possible to say that because the students have conducted hypothesis experiments and are able to form their own conceptual understanding; they have reached the highest level of learning. It is much more complicated; because the best performance may very well be a result of move testing – or a combination of all three methods. But hypothesis experiments imply a larger degree of implementation – often the students' creative ideas are very elusive – they often disappear again. This is one of the dilemmas of creativity research – how to secure and implement the creative ideas without killing creativity.

Helped through facilitation the experiments can contribute greatly to give students the opportunity to build on several types of experiences, analysed in relation to one another. Similarly, it is clear that experimentation helped by facilitation can move through all of Schön's three categorisations.

4. EXAMPLES

In the following we will describe three examples of how we use the experimental approach in our courses.

4.1. Project management

In the CLP course we stress the necessity of being able to plan, control and lead the project of the group. This means that the students have to find out how much time the group has for the project, how many resources that are available, and which activities the group wants to include in the project. During the course we show various examples of how to make activity diagrams linked to time schedules. Among others we show a Gantt schedule (Gantt, 1999) and we invite the groups to experiment with the various possibilities to develop a tool, which fits their requirements.

The students work in very different ways with this field. In the beginning of their study many find that it is not necessary at all, others try to get an overview, and some groups make persistent efforts to make a usable tool for project management. By examples we can illustrate the students' approaches according to Schön's categorisation of experiments.

The Explorative Experiment
The students make a calendar on a sheet of paper, which can have many sizes and be more or less decorative – or they make a calendar on their computer. The group's argument in favour of this experiment is "if we make a calendar and enter all our activities on the respective dates, we will be able to see how we can manage to finish our project in due time". Often nothing else will happen with the calendar, if the supervisor does not make the group experiment further e.g. to Schön's next category: move testing or even further to the hypotesis testing experiment. The supervisor may e.g. ask: "How do you want to use the calendar? In which way will it contribute to your project management?"

The Move-testing Experiment
Based on the student's own experiences and reflections they can develop the calendar, or the above questions can initiate further work with the calendar. The students use the activity calendar and enter activities as they become actualised or as soon as they are planned. "We should allot time for our visit to a company and then add an activity called "further considerations" after the visit". They are also aware that they have to enter all known activities like courses, days off, meetings with their supervisor etc., as these activities leave less time for the students' work with their project. Suddenly, the group realises that they do not have as much time for the project as they immediately thought.

In this experiment the work is a process which is never finished and everything happens at random. There are still many surprises and unforeseen tasks which are not on the calendar. But the students gain a lot of experiences, and it is important to work with the experiences and

generalise them, and in most cases supervision is needed the first year. To proceed, the supervisor may e.g. ask: “How will you make your activity diagram for the next project? How will you avoid all the surprises, so that you have sufficient time for the activities you find important for the project?”

The Hypothesis Testing Experiment
These questions initiate the hypothesis testing experiment. The students try to estimate the duration of the various activities, and based on former experiences reach the conclusion that they have to add “buffer time” to special activities like e.g. contact to external companies, which cannot always take place when it suits the group. And for specific laboratory tests they have to calculate time for transport of the group members, time for arranging the test set-up etc. Actually the students are using Schön's "what if"-. The group may decide to test whether some activities can be made more effective by e.g. working out calculations in small groups, making a system for writing and reading work papers, and deciding on a certain lay-out from the beginning.
This testing experiment implies that the group sets up measurable criteria and decides how they will carry out their tests.

4.2. Contact between Students and Supervisor

Another aspect, which the students learn during the CLP course, is the necessity of drawing up a contract for the co-operation between the group and its supervisor and between the members of the group. This is essential in order to discuss e.g. expectations, which have a large influence on the co-operation in the group and their relation to the supervisor. We give the students various examples of contracts, and we invite the students to work with the contracts and develop them further.

The Explorative Experiment
The students draw up a contract based on the model shown in the course and the students and the supervisor go through the contract. It may be that the contract is discussed and accepted by both the students and the supervisor – but they do not discuss how to use the contract. The supervisor can start a discussion of how to use the contract and thus move to Schön’s next category.

The Move-testing Experiment
The students agree to revise the contract every month and changes are made according to the problems, which the group finds it, necessary to handle. It might be that some of the students in the group never keep the deadlines for delivery of papers to the project and that the supervisor is not prepared for the meetings. The students discuss the problems in the group and they agree that many deadlines have been unrealistic, and that since the supervisor have only received the group’s papers a few hours before the meeting, he has not had a chance to read their materials. The group decides to be more realistic with regard to deadlines and to add to the contract that the supervisor should receive the materials from the group at least 24 hours before a meeting.

The group has now taken a step forward, but they can make it even further in their use of the contract if the supervisor facilitates the Schön question “What if?”

The Hypothesis Testing Experiment
The group estimated that their difficulties in keeping the agreed deadlines could be caused by the tasks being too difficult and deadlines unrealistic, by too many other subjects which also demand an effort, or by other problems preventing the students in question from keeping the deadlines. From various hypothesis the group discusses what may be the reason why the deadlines are not kept. The answers offer an opportunity to test the hypothesis.
The group decides to find out how they can find a solution to keeping deadlines, and decides to organise themselves in small working groups, to define the tasks more precisely, and to evaluate this re-organisation every month by their ability to keep deadlines. They also plan to prepare a commented agenda for the supervisor meetings with deadlines for each item in order to make sure that all items are discussed.

4.3. Co-operation

A basic factor in the CLP course is that on one hand the students understand the terms of co-operation and the potentials of the project organised group work and on the other hand understand how the individual and collective learning processes work in this organisation. During the course the students receive a number of tools and methods of how to handle possible co-operation problems. They learn how to use a communication diagram, by which they can see how communication works between the various group members. Furthermore, they learn, that in every group the members play various parts, which influence the co-operation (cf. Belbin) and they learn about conflict analyses and conflict resolution. The following is an example of a group which has problems because two of its members talk most of the time when they are working in the group, they interrupt the others and they both fight to become the leader of the group. This means that the rest of the group spends much time hearing the two students discussing and quarrelling. The co-operation has gradually become very poor.

The Explorative Experiment
The supervisor calls the attention of the group to the fact that the two talkative students must respect the other members of the group and listen to what they have to say. At the next meeting the group decides to improve their co-operation. They make a communication diagram showing how communication works in the group, and they see that two of the students talk a lot with each other all the time, and that some hardly speak. The group states that communication is very poor and that it has a bad effect on their project work. By asking the group how they intend to improve communication based on the information from the communication diagram, the supervisor can make the group proceed in their communication experiments.

Move-testing Experiment
The group decides to improve communication so that it is not the same persons who talk all the time, and that they will make a communication diagram at every meeting. They will also appoint a chairman and a notetaker. They make communication diagrams and take notes, but the chairman does not know how to handle the two talkative persons, who are still interrupting and talking a lot. In this situation the supervisor can ask how the group wants to progress in their improvement strategies. “What would improve communication? – What if?" This question leads the students to different hypothesis.

The Hypothesis Testing Experiment

The group discusses that the chairman should have some powers so that she knows what she can do – and everybody must accept these powers in the group. The group decides to write down the powers of the chairman – e.g. that the group members have to put up their hand when they want to speak, and that chairman leads the meeting according to this. They decide to test this way of leading the meetings at two meetings, and at the same time the members of the group will change seats, so that they have different seats every week (they have learned this at the course). They will make new communication diagrams to see if these initiatives will improve communication.

5. PERSPECTIVES

Teaching and learning process competencies is very difficult, because it seems banal to the students as it is based on experience and development – but at the same time it is difficult because it is about development of one's own competencies. Based on many years of experience in teaching these subjects, we have no doubt that teaching should be organised on the basis of the experience-based learning paradigm. Learning methods within this paradigm implies among others reflection and experimentation.

In our courses we have been good at dealing with reflection – and we have had a basic understanding that the experiment is also an important learning strategy especially for engineering students. But it is not until now, when we are about to take the consequences of our knowledge that we work deliberately with various types of experiments and use the simple "what if to make students make the experiment before they formulate their final reflections.

If there was no experiment there was nothing to reflect upon – if there were no reflection, trial and error would dominate without further thought.

Furthermore, the experiment is an important element in developing creativity – but to prevent creativity from ending in elusive ideas without any kind of implementation, the students have to learn to jump from the explorative and common sense level, to move-testing and comparative reflection, and further to hypothesis testing and conceptualisation. The students also have to add terms to the various types of experiments and relate them to their own learning strategy.

Knowledge about the various types of experiments can support the supervisor when she/he gives advice to a group on how to continue their work with the experiments. And there is no doubt that the students will move much faster through these learning processes by facilitation than if they have to explore everything themselves.

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