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Training key skills for Concurrent Design

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INTRODUCTION

Concurrent Design is an approach to collaborative engineering that requires tight interaction between domain experts from different disciplines. It requires team collaboration as well as complex modelling and analysis in a concurrent and iterative setting. The skills required for the Team Lead supporting the CD process are ranging from analytic skills such as system engineering and modelling to soft-skills such as creating shared understanding, process guidance and handling team dynamics. In this paper we analyse the key tasks of a Team Lead and explore the skills required for each of these tasks. Next, we share our experiences with training methods and exercises that support the development of these skills.

CONCURRENT DESIGN SKILLS

Concurrent Design as an approach is often described using five pillars, the team, the process, the decision tools and methods, the facility and the integrated design model [1]. Each of these pillars needs to be integrated to create an effective concurrent design effort, and consequently each gives rise to a set of tasks and skills to support this effort.

To start, the team pillar requires the Team Lead to do a stakeholder analysis, to do team building, to create shared understanding, fostering commitment and ownership and of course team motivation. For this pillar, a Team Lead needs strong group dynamics skills, and needs the skills to make interventions in the team.

The process pillar gives rise to tasks like process design, process guidance, conflict resolution, but also to managing time, progress and scope. For this pillar the Team Lead and System Analyst need strong time and project management skills.

Next, the decisions in Concurrent Design require the Team Lead to choose and apply decision methods, and to structure information to support decision making. It also requires the team lead to deal with bias and the roles and stakes involved in the study, as well as the identification of design trade-offs and supporting solving them. Also, both the Team Lead and the participants need to learn how to deal with uncertainty in the design.

The Fourth pillar is the facility, it supports the Team Lead in fostering a collaborative environment, but it also comes with key tasks to make optimal use of the hardware and software involved. For this pillar the Team Lead should understand and harness the power of visualization, using it as an instrument to increase shared understanding and to support information exchange and communication among the participants, in an effective manner. The use of information technology further comes with the responsibility for information security and the management of data and data quality. In these tasks the Team Lead can be supported by IT staff as well as a system analyst, still as the end-responsible for an effective CD effort, the Team Lead needs to understand and apply these functions.

Finally, a realm of tasks derives from the Integrated Design Model (IDM). To support collaborative modelling the Team Lead needs to guard the System Engineering principles and to affirm, apply and guard the modelling syntax and rules to monitor model quality and consistency. Further, the Team Lead needs to understand the modelling process and manage the model iterations and balances.

A list of tasks per pillar are described in the table below.

Table 1. Concurrent Design skills

Team	Process	Decisions	Facility	IDM
Stakeholder analysis	Process design	Select decision methods	Creating and effective work environment	Support collaborative modelling
Team building	Process guidance	Structure information	Manage data	Guard SE principles
Develop shared understanding	Conflict resolution	Deal with bias	Manage communication	Guard model quality
Foster commitment	Time management	Support decision roles	Managing data quality	Guard model consistency
Foster ownership	Progress management	Identify and manage trade-offs	Use visualization	Manage modelling process
Motivate	Scoping	Deal with uncertainty	Manage data security	Manage iterations

Given this broad palette of tasks and the often limited time to train Team Leads, effective training methods are required targeting specific skills, next to the obvious learning from example, hands-on, as participant or system analyst in a concurrent design team. One of the key challenges in this respect is the fact that the team dynamics of a larger group (typically Concurrent Design studies involve 15-30 participants) are difficult to simulate in a training setting. Emulating a study in a small training group may not feel the same, and may not pose the right challenges for the Team Lead to practice for instance conflict resolution or focussing discussion.

To support the training in this setting, we created a set of (role-playing) games that specifically target these skills. These games are set up in a way that enables the trainee to practice close-to-reality scenarios in a short time frame. Another challenge is the time it takes to run a full design cycle even for a simple system. A solution we created here is a fully scripted and pre-engineer simulation game that enables the team to walk-though a full design cycle without the need to actually 'do' any of the engineering. Finally, a third example of a game is one aimed at a more specific skill required for Concurrent Design, dealing with uncertainty in early design phases. These games help us to train focused aspects of Concurrent Design in an efficient and fun manner. Below we will explain some of the games, and the way they support building Concurrent Design skills. First, we will explain why we use games.

ROLE PLAYING TO TRAIN GROUP DYNAMICS

The rationale to use (serious) games in our training for Concurrent Design involves several key reasons:

1) **Authentic Environment:** the games provide an environment and tasks that are authentic to concurrent design skills. This allows learners to practice skills in a context that closely mirrors real-world situations.
2) **Safe Space for Learning:** the games represent a safe space where learners can make mistakes, correct themselves, and try again. This elimination of the fear of failure contributes to strengthening self-confidence.
3) **Effective Learning Method:** the games incorporate sound learning goals into their design and structure. They are proven as an effective learning method for conveying skills on complex tasks [2].
4) **Motivation and Engagement:** The use of the games and game-based learning has shown a strong effect on motivation and participation. The trainees experience the setting and experience near-real examples without the worries of a real CD study.
5) **Application of Knowledge:** the games not only re-iterate on the theory, but also how this knowledge is applied.
6) **Feedback Mechanism:** Games' immediate response to actions might offer the kind of feedback mechanism to trainees that helps them to reflect on their difficulties in a safe setting.

In summary, serious games offer a unique combination of engagement, safe experimentation, immediate feedback, and practical application, making them an effective tool to train hands-on skills required for concurrent design.
We will explain and illustrate some of the games we used below.

ROLE PLAYING TO TRAIN GROUP DYNAMICS

The first game comes in two versions, each train a specific aspect of group dynamics. The learning goal of the first game is to learn 'handling interruptions' it belongs to tasks like team building, conflict resolution, and fostering commitment and ownership. In this game we play out short scenario's where a stakeholder in the Concurrent Design session is unhappy and 'disrupts' the session. This can range from passive aggressive behavior, to angry participants that threaten to leave. The game starts with a very brief introduction of the scenario. The trainee that practices the Team Lead role is asked to

kick off a next step in the discussion. Each of the other trainees plays a role as stakeholder or subject matter expert, except one. One of the trainees has the role of disturber, who is not known to the trainee-team lead. Once the discussion is on it's way, but within 2 minutes the disturber creates a challenging situation for the Team Lead trainee based on some pre-given instructions. The Team Lead trainee has to respond to the situation and they role play for a few minutes. Then the game is cut off by the trainer. The trainee and the group reflect on the situation and exchange ideas on how to handle the situation. Finally the trainer gives the group feedback on how to deal with the specific group dynamic's involved.

This game works well because the scenarios are realistic, and the team lead trainees are surprised by the situation. This forces them to really solve the situation, and the experience is very similar to a real session, but in the safe setting of the training, allowing them to make mistakes. Each trainee gets a turn in being team lead and being the disturber. Both perspectives help to experience the situation and to empathize. When training like this, the Team Lead trainee can reflect on their role and tasks in process guidance, but also practice and experience how they stand their ground in a conflict situation in front of a large group. The set-up helps the trainees to zoom in to tricky situations that in real-life only occur rarely, but where the Team Lead skills are really tested. The approach is also efficient as the trainees learn from each turn, even if they only play the role of group member. Furthermore, the role-play can be really short 5-7 minutes is enough to feed a 15 min reflection.

ROLE PLAY TO EMULATE A CD STUDY

The emulation game is meant to introduce people to concurrent design so they can 'experience' it, rather than just listening to a presentation about concurrent design. This game is used to give a group of people insight in the overall CD process. Naturally, the best way to experience a CD study is to participate in one as Subject Matter Expert. However, before an organisation or team decides to adopt Concurrent Design, they need to understand what it means and how it works. This game helps them in that. We used the game in three different scenarios.

1) For open training sessions, introductions and site visits of a CD facility [3].
2) As a training before the start of a CD study, to introduce the team to the approach
3) As part of a CD training program to give participants a joint frame of reference when discussing aspects of concurrent design.

We have different versions of the game using different domain cases (e.g. designing a drone, freezing the design of a maritime vessel, designing a radio system) and we created version with different levels of complexity, ranging from short and simple to more complex and involving first experiences in collaborative modelling using CDP4-COMET as well.

The set-up of the game is a follows. First, we start with a short theoretical explanation of concurrent design. Next, the participants are assigned a role each. The game simulates 2-4 CD sessions, depending on the complexity. For each session they receive a role description. In the first round, we simulate the first session. The trainer/Team Lead explains the scenario and asks each participant role about their domain of expertise, and whether they are mandated to represent their domain in the study. Next, in the first session we explore the challenge. Each role adds a problem or challenge to the design. Some bring in requirements, others offer solution directions or challenge them. The description is such that some aspects are obviously vague, and these are assigned as 'homework' to the participants in their roles. In the next round, we simulate session 2. Participants receive a new role description in which their 'homework' is done. In this session solutions and option are further explored and we start to combine data from the different description in an integrated design model. We show participants how the model will support their design decisions, and how it helps to verify requirements using a design model. We wrap up the experience with explaining how Concurrent Design support the team in collaboration and creating shared understanding. We then reflect with the participants on how they experienced the game and what questions they still have about Concurrent Design. When used as a training session, the game is also used to explain participants what is expected of them.

A GAME TO TRAIN DEALING WITH UNCERTAINTY

The last game we discuss in this paper is a game to train participants in dealing with uncertainty. In many Concurrent Design studies, the team operates in an early phase of the design process. Some information is still unavailable or unclear. However, one of the key principles of Concurrent Design is to create the first system level budgets and balances early. This helps the team to scope the design on time and to identify design trade-offs early in the process.

The game set up for this learning goal is a tower-building game. The game is most fun when played with 2 or more teams of 3-4 participants. Each team receives a set of blocks. First they receive a test – set, a limited number of blocks. Later they receive a full set. With the test set, each team gets 15 minutes to create a design with the objective to build the highest tower possible. They need to create a design that is feasible to build within 10 minutes. Before they start building, they need to hand in the design drawing and the estimated height of the tower. When specifying the height of the tower they are asked to provide a margin of error.

They then build the tower with the complete set of blocks, and it's actual height is measured by the trainer/Team Lead. We then compare the results with the estimates and the margin of error. Many teams will be quite close despite that they did not build the tower yet, and neither had precise information about the size of the blocks. The lessons learned include how to estimate under uncertainty and how to deal with uncertainty in the design. Further, often teams create small design models to calculate their estimates based on the repetition of blocks in the design.

As this game teaches a more detailed aspect of concurrent design it is used mainly in advanced training sessions both for domain experts as well as for people that train to become Team Lead or System Analyst.

A picture of one of the tower games can be found in Fig. 1.

Fig. 1. Tower game

CONCLUSIONS

The games described above are a big success in our training sessions [4]. The games help to create a shared experience that encourages learning, but is also fun and a welcome break in a day of training. Using the games we help our trainees to learn the principles of Concurrent Design faster and more effective as the experience 'sticks' better than theory presentations. At Starion we keep improving our training portfolio, both for Concurrent Design as well as for MBSE. For the latter we're looking into new ways to train participants in key modelling challenges and best practices in MBSE.

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