Diggelen, M.R. van and Doulougeri, K.

A project funded by the 4tu/e Centre of Enginering education and the Bachelor Colllege

Coaching students working on complex design challenges of a multidisciplinary nature

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## Introduction

This document describes the results of an innovation project, funded by the 4Tu/e Centre of Engineering and the Bachelor College, on how to coach students that work on Complex and Multidisciplinary Design Challenges (CDCM). To do so, findings were integrated from interviews with Industrial Design Teachers, observations of coaches who worked on complex design challenges, a data team intervention study with teachers from a USE course, and a literature study. This process led to the formulation of guidelines for effective coaching (for an overview, see the next page). Members of the project team, educational experts and the teachers of project robots reviewed these guidelines. Based on their input we adjusted the guidelines. The final version of these guidelines is presented in this document. In Chapter 3, each guideline is presented and explained. Based on these guidelines we developed a self-assessment tool and peer-assessment tool to support teachers in developing their coaching competencies.

While reading it is important to realize that the project was based on the following premises:

* The thinking process of designing involves a convergent and a divergent component. The convergent component is strongly embedded in engineering’s curricula whereas the divergent component receives less attention. It is precisely the divergent component that is addressed in complex and multidisciplinary design challenges.
* Stimulating divergent thinking and fostering innovative and creative thinking and making skills that are required when dealing with open and complex design challenges is difficult. Many coaches with a background in engineering have not been trained for such a role. Also, these coaches have probably not witnessed a (good) example of coaching students in divergent thinking when they were a student themselves. As a consequence, the coaching of many engineers will be influenced by a ‘traditional conception of engineering design’.
* Differences in coaches’ conceptions of engineering design can have a severe impact on the coaching of design processes.

In this text the word design will be used very often. If the term design refers to the general activity of designing and not to a specific conception of it, we actually mean engineering design.

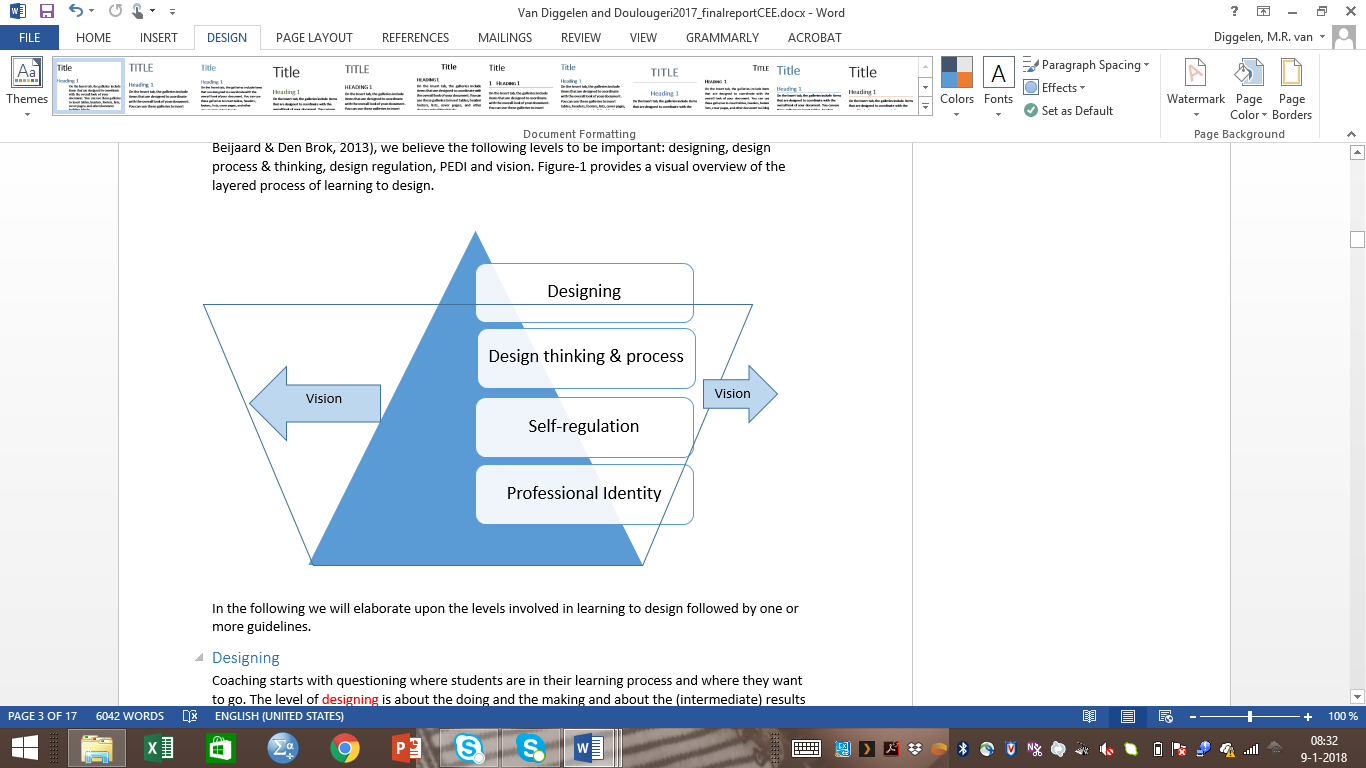
We hope this document is helpful for teachers in order to stimulate reflection on their coaching practice.

Migchiel van Diggelen, Karolina Doulougeri, and Elise Quant with the advice of Angela Tops, Ruurd Taconis and Stephan Wensveen.

## Coaching during the whole project to ensure optimal learning.

### Different levels of learning in design-based learning.

Design challenges are often ill-defined. When dealing with these issues students go through a non-linear and non-iterative process. It works best when both coaches and students do not have an a priori conception of an outcome. In this way, the design deliverables will emerge from the design process. In the process of designing, students need to learn to see, to think, to make decisions and to focus when they experiment and find their own way. Learning these skills implies learning at different levels. In coaching, effectiveness is enhanced when coaches target the right level at the right moment. Explicitly addressing the topics makes the interventions more specific and therefore better directs students’ attention to the right aspects. In line with the conceptual educational model of Industrial Design (Bruns & Van Diggelen, 2017, p 51; Hattie and Timperley, 2007; Van Diggelen, Beijaard & Den Brok, 2013), we believe the following levels to be important: designing, design process & thinking, design regulation, PEDI and vision. Figure-1 provides a visual overview of the layered process of learning to design.



F-1. Layers in learning to design 1

In the following we will elaborate upon the levels involved in learning to design followed by one or more guidelines.

#### Designing

Coaching starts with questioning where students are in their learning process and where they want to go. The level of designing is about the doing and the making and about the (intermediate) results of the design process. This level strongly corresponds with what Miller (1990) calls the demos: what is visible. The level of designing can be used to make implicit thinking processes explicit with reflection on action and linking the making to the thinking, but it can also be an intentional process wherein students formulate goals they want to realize. As becomes clear by now, this level is often the starting point for coaching on deeper levels. It can be used to make the thinking while designing explicit and to discover the underlying rationale. As already stated, coaching interventions are the most effective when they are embedded in what students have done or created in their design process. Coaching won’t actively engage students when it does not build on an experience, image or insight students have or does not fit their frame of reference. Ideally, coaching on the design process always starts with something the students have done or thought of. A next step in the coaching, then, is to switch to the thinking and process level of designing and to continue with deeper levels of learning.

Guideline: The effectivity of coaching is enhanced when coaches actively undertake ‘expectation and learning-outcome-management’ and stimulate students’ to explicate learning experiences and outcomes from the start of the project to the assessments.

Projects offering open and complex design challenges resemble the professional practice engineers will face in their professional career. Student teams, for example, have to deal with uncertainty, unpredictability and the interests of different stakeholders. To cope with CDCM, students need to develop skills associated with being a good designer (Dym et al., 2005). According to these authors students need to learn to:

* tolerate ambiguity that shows up in viewing design as an inquiry or as an iterative loop of divergent-convergent thinking;
* maintain sight of the big picture by including systems thinking and systems design;
* handle uncertainty;
* make decisions (based on too little information);
* think as part of a team in a social process;
* think and communicate in the several languages of design.

All these things have to be learned in a situation wherein students have lots of freedom and are provided with little structure placing a strong emphasis on students/student teams’ self-directedness. In these circumstances, students can easily get lost and perceive difficulties in finding out what is expected of them. In particular, when students have little experience in undertaking this kind of open projects, students need to get used to the openness, the little structure, the freedom and the responsibility for managing the process themselves they need to deal with in CDCM. As a consequence, it is very important that coaches explain what is expected of the students, namely that students experience the process, find their own and learn by discovery and use the freedom, ambiguity and openness to develop a self-directed attitude and skills to direct their own process and explain the relevance and usefulness of this way of learning.

As in real working life, student teams are confronted with many (learning) processes that run simultaneously and are intertwined. Students are thus provided with many opportunities for learning. These opportunities for learning often fuel implicit learning processes that take place without conscious registration of students. It is therefore likely, that students learn more than they realize. This can go at the expense of the students’ project experience and overall satisfaction. It is a challenge for coaching to make students aware of these implicit learning activities and to help them verbalize their learning experience and outcomes.

### Design thinking & process

A large part of the design process is not intentional and is done based on intuition and or just by doing. In these instances, students do not consider and think of the impact and consequences of choices. Students often just do. Actually, it is learning by doing. So, students need to reflect and learn from their experiences in order to raise awareness, develop insights and/or to be confirmed in previously developed insights. It is important for students to become aware of their own design approach. This awareness and reflection on experiences then, can be used to improve their process and make deliberate decisions. The process of becoming aware of one’s design approach and learning from experiences is facilitated by a constant articulation of the underlying thinking processes, rationale and on how the process is unfolding. It is the challenge for students to find out what they are thinking when they generate good work. Objects and other deliverables, then, can be used to carry the message across and help students to explicate their thinking.

Guideline: learning to design will be more effective is coaches constantly stimulate students to articulate their underlying thinking, the rationale and how the process is unfolding when they are generating good work.

### Self-regulation

CDCM are projects wherein student teams need to be self-directive and are supposed to explicate, narrow and structure their own learning and design processes, reflect on the process and regulate or adjust their approach. Coaching students during these types of projects should always be focused on supporting and challenging students to develop metacognitive knowledge on how they regulate and need to regulate their own design process. This metacognitive knowledge will help the students to apply the gained insights in the next iteration. The level of self-regulation is the level where coaches intentionally empower students and stimulate students to learn how to act independently. The better students are able to regulate their own design process the fewer constraints a coach will place.

Guideline: Coaching will be more effective when teachers deliberately constrain the design process

Students working on CDCM have to deal with many different processes in parallel and have to make many decisions during the design process. Students need to learn to deal with this freedom, to make the right decisions and to manage their process. Setting the right constraints will guide students through the design process and lead them through a process of self-discovery, exploration, experimentation and active learning. Constraints can, for example, prevent students from following their instincts, start from one of the initial ideas and rush through the process by following this early idea. Depending on the stage of the design process and the activity to be undertaken the constraints get the shape. It is important for coaches to develop insight into the tendencies that students demonstrate when learning to design. Knowledge of these tendencies makes teachers alert to situations or moments in the design process where it needs to be a constraint. An example of constraints a teacher can set are: not to comment on the aesthetics of deliverables to guide students away from a focus on the intended final product (Sawyer, 2015). Another example might be that coaches do not provide specific answers because it prevents students from going to the process themselves.

Guideline: Coaching will be more effective when adhering to requirements of embedded formative assessment and the questions where students are, would like to go and how to get there are explored and answered.

Providing students the opportunity to articulate where they are in the design process helps the student to learn how to see both their own work and the work of others. It provides them with input to reflect on why a design activity they have undertaken was unsuccessful or successful. Mismatches between students’ intentions and their actual work are very useful for students and provide them with input for reflection. It also supports students in stating where they would like to go to with their process and how to realize it. A frequent source for input is the mismatch between students’ ideas on what they have done or are still doing and what the work demonstrates. Coaches guide students to see this mismatch. So, coaching sessions can be structured by exploring and co-construct where students are, where they would like to go and how they will get there with respect to design processes. In the ideal case, students are able to answer these questions for themselves. In each case, students should answer these questions for themselves when preparing the coach meetings.

### Professional Engineering Identity Development

Learning to design encompasses more than just developing knowledge, skills and competencies. There is ‘something more’ to it. Students’ PEDI has been mentioned in this respect (Lawson & Dorst, 2015). A PEDI is about how a student views himself as a future professional designer. The PEDI development requires the integration of one's personal traits, motives, competencies, values, morals, beliefs and attributes with the norms of the profession and technical knowledge. The DPI includes the awareness and understanding of the self in the design sphere and what is expected within that space. Students must learn to see who they are as a designer and how their PEDI affects their professional work (Tracey and Hutchinson, 2015). Explicitly paying attention to the PEDI of students is important because actions in the design process are a manifestation of it. Developing self-knowledge will help improve future action in the process. To become successful in integrating new design approaches the students have to become aware of their own conception of design and how it varies from others. To illustrate this, it is often the designer who generates, selects, tests, and refines ideas in order to better understand the problem and develop solutions. Thus, it is important for designers to understand how they influence this process via their personal experiences, beliefs, and actions, particularly as they relate to the affective aspects of the design process (Hutchinson and Tracey, 2015). A coach should play an active role in making the student understand how elements of his PEDI affect the design process. It will stimulate deep learning when students learn to see deeper levels of their behavior and link their behavior to it. Deep learning, will increase the likelihood of transfer of knowledge and skills. Explicitly addressing the DEPI will help students become aware of their unique characteristics and how to distinguish themselves from colleagues. It will build confidence and help to foster professional development. Having self-knowledge and being aware of their PEDI provides students with stability in the uncertain, ambiguous and open design challenge and process. But above all, coaches can use this level to make students aware of the professional practice and their profession. It is the level to make the learning thoroughly authentic.

Guideline: Coaching will be more effective if students are challenged to explore a teachers’ PEDI and (in the long run) develop insight into the range of existing design conceptualizations.

Challenging students to explore the PEDI of the coach is important for several reasons. Firstly, in the near future, the need for cross-disciplinary collaboration in complex design challenges will increase. Cross-disciplinary collaboration and innovation will require the understanding of variations in the ways people experience and make meaning around design. Understanding the design conceptualizations of the others will likely increase opportunities for innovation and a lack of understanding or the disability to leverage the conceptualizations will likely limit the opportunities for innovation.

Secondly, making the design conceptualizations of a coach explicit will reduce its implicit impact on students’ learning and likely keep the learning more discovery-oriented. How a coach conceptualizes design will strongly influence what he sees as important in learning, what he expects from his students, what he sees as a good design process and where he will focus on in the coaching. Next to the beliefs of the coach, also his values, norms, competency profile and specific expertise strongly influence his coaching. The PEDI of the coach will manifest itself in coaching. Coaching, then, is a reflection of the PEDI of the coach. The challenge for a coach is to make his PEDI explicit and subject for exploration by the students without unnecessary influence how students frame design challenges, go through design processes and create deliverables.

Thirdly, a coach should challenge students to explore his PEDI because of its contribution to students learning. It will help students to better read coaching interventions and to benefit more from the specific expertise of the coach. It will also help students to develop their own PEDI, expand their design repertoire and will be supportive of them in dealing with the complexity and ambiguity of ill-defined problems and professional practice. Finally, the increased awareness and understanding of different design conceptualizations may be beneficial for students in teamwork requiring multidisciplinary collaboration. .

### Vision

A vision is an inspiring and coherent set of ideas and beliefs about the future of society, emergent technologies and the future role of academic designers or design researchers in shaping that relationship. A vision offers a long-term perspective and indicates how something will be, should be or can be interpreted. It helps students to determine their PI and to further direct their PEDI development. Reasoning backward from a vision, students can deduce competencies that are needed in the (near) to already become the (design) engineer of the future. A vision should have a clear focus to serve as a point of reference and should be connected to the PEDI. In coaching the level of vision can be addressed as a starting point for supporting and challenging students to define a unique PEDI that helps them to distinguish themselves from others.

## Prerequisites for effective coaching

Coaching will be more effective in a safe and stimulating environment

In order to open up, think freely and share their thoughts with both fellow students and the coach it is important that students perceive the environment as safe. Furthermore, if students perceive the environment as stimulating they will likely be more actively engaged.

Coaching will be more effective when dialogue amongst the project team is stimulated.

Students work in project teams. In these projects, students are supposed to collaborate and strive for realizing as a team more than the sum of the contribution of all the individual members. The dialogue between the members of the group and peer feedback exchanges are important in this respect. Dialogue and peer feedback can improve students’ reflection and lead to students interacting with different conceptualizations. However, for various reasons, it can be difficult to create a dialogue, and ask for and provide honest and constructive feedback to fellow student members of the team.

A first reason, is that students often do not know each other before the start of the project and that relationships need to be established. To create a dialogue and ask for and provide ‘honest’ feedback to each other and function like a team, time and experience with this kind of processes are needed. Relationships need to develop in such a way that it feels safe enough for students to engage in a dialogue, to ask for and provide feedback, and to believe their actions are appreciated. Coaches can help to facilitate and start this process by emphasizing it in their coaching, by actively intervening to realize the conditions for this kind of coaching and by facilitating a dialogue between the students in the meetings.

Another reason pertains to the fact that students oftentimes are from different majors and therefore come with their own but different frames of reference to the meetings. The students have another competency profile, speak another disciplinary language and likely have different thoughts and beliefs about the design process and outcomes. It is important that coaches make students aware of these differences in perceptions, in background and profiles, help them to understand these differences and potential implications, and help them overcome these communication issues. Next to understanding and showing respect for these differences, it is also important that students demonstrate the will to learn from these differences, have an open attitude and embrace the differences in order to create a shared dialogical space and strive for mutual understanding and joint exploration of new topics.

A successful group is thinking together as a group and its members identify with the dialogue between group members and not so much with themselves or the group (Mercer & Wegerif, 2003). In such a group, there is an opportunity for dialogue characterized by openness and a multiplicity of voices. It is the mutual exploration and meaning-making that is deemed important and not the ownership of ideas. These dialogues reflect and build on the students’ PEDI. The conversations are by definition personal due to the fact that students’ identities become manifest in these conversations. It places an emphasis on the importance of trust in each other, acting emphatic and providing the opportunity for students to learn from the dialogue.

## Coaching, communication and dialogue.

Coaching will be more effective when all stakeholders approach it as a continuous dialogue.

The idea is that dialogue is crucial for successful learning. A successful dialogue, however, asks for an intentional arrangement of the coaching situation and context. Effective interaction and dialogue only take place within a context of mutual understanding. In such a context, students are able to imagine, understand and relate to the frame of reference of the coach and the coach is able to image, understand and relate to the frame of reference of the student. Furthermore, both the students and the teachers interact in the context of a shared frame of reference. Either, these conditions are established before the conversation or realized during the conversation.

A dialogue actually consists of a continuous feedback loop. This loop provides teachers the opportunity to check whether the intervention has the intended effect or not. A coach is, for example, able to check whether or not a hint is taken, a question directs the attention of the student in an intended way, generates the proper knowledge, results in active engagement of the student or fosters thinking. Actually, interventions also fulfill the role of formative assessment wherein evidence is collected to determine to what extent the intended effects are realized and why so. If not, the information can be used to re-intervene. A continuous loop is also of use to students. Such a loop provides students with the opportunity to respond to the coaching intervention, to ask for clarification, to comment on it, discuss it, elaborate on it, nuance it or takes the conversation in a different direction if a student feels the need for different input.

Mutual understanding in the context of an open and complex design project also means a mutual ‘unknowing’. There is not a single right answer that is already predefined. As a consequence, (a mutual) exploration of topics is inherent to coaching in CDCM. Added to that, it is important that both the teacher and the student take part in the dialogues with an open mind and have no fixed preconceptions of both the design path/process and the outcomes. If predefined conceptions exist an actual dialogue will not develop. If coaching conversations unfold without a shared understanding and frame of reference it is very likely that miscommunication arises and that the intentions of both the coach and the student won’t be realized. This problem of ‘misconception’ is widely recognized within the educational literature. If the conditions are seriously threatened they should be subjected to a meta-conversation and the topic of the conversation should be about how to (re)assure these conditions.

What are actually the characteristics of a successful coaching dialogue? Laurillard (2002) compiled an influential theory and distinguished several characteristics to underpin effective dialogue. According to this author a dialogue should be:

* aligned with students’ needs (adaptive);
* rich in two‐way communicative exchanges (discursive);
* linked to actions related to a task goal (interactive);
* Encouraging students and teachers to reflect on the ‘goal–action–feedback cycle’ (reflective).

Guideline: Coaching will be more effective when teachers deliberately pay attention to the communicational aspects of coaching.

Adequate verbal communication is an important prerequisite for effective coaching. According to pioneering scholars of communication theory (Watzlawick, Bavelas, Jackson, 1967), communication has at least two aspects, namely the content and the relationship. Both can influence one another. A positive relationship is likely to have a positive influence on the content dimension whereas a negative relationship is likely to have a negative influence on the content. In line with the aforementioned communication theory, coaches need to pay attention to the relationship with the students and assure that there is a good relationship and students feel free to speak out. With respect to the content part of communication can be said that it is crucially important that the message of the coaching intervention lands or is provided with a context. Attaching a message to a context enables the student to give something meaning, to make it stick and to use the information in future situations. Obviously, the context is oftentimes the design process or deliverables. Next to the context, it is needed that students understand the intentions of the coach and vice versa.

Research shows that teachers often believe that students are aware and understand their intentions when directing their coaching interventions whereas students are actually not. Often, the intentions of the teachers remain implicit or are too complex or vague for students to understand. As a consequence, it is difficult for students to find out how they should interpret, value and give meaning to the coaching intervention of the teacher and to decide what to do with it. To remedy this, teachers need to pay deliberate attention to the communicative aspects of coaching. Preferably, teachers explicate their intentions in simple, descriptive and non-ambiguous words assuring that a student will interpret and understand the intentions behind the intervention. As said, such an understanding is important for the effectiveness of the intervention and will likely lead the intervention to focus the attention of the student on the right aspects. Whether or not the attention of the students is focused on the right aspects strongly depends on form-giving dimensions of coaching.

Form-giving aspects of communication influence the effects of coaching interventions. How a coach formulates his intervention depends on the intentions the coach had and the specific nature of the interventions. For questions, for example, it is often important that they invite a student to think. For feedback, on the other hand, it is important that it is descriptive and formulated in a non-judgmental way assuring that the attention of the student is not distracted by it.

Guideline: Coaching will be more effective when a coach adequately applies conversation skills.

As said, coaching needs to be approached as a dialogue between teacher and students. The coach has an important task to start the dialogue. Conversation skills are of eminent importance for starting and maintain the dialogue. Conversation skills are basic skills. Examples of these skills are: asking open and closed questions, active listening skills (e.g. ahum ahum), paraphrasing, summarizing, asking for clarification, a reflection of feelings and positive relabeling. Possessing these skills, using them deliberately being able to observe and evaluate the effects is a condition for effective coaching.

## A toolbox of interventions

Guideline: Coaching will be more effective if teachers deliberately make use of different coaching interventions (see appendix-4).

In the literature on formative assessment, feedback, coaching and scaffolding, similar coaching interventions are described, namely: instruction, scaffolding, modeling, providing feedback, providing tips and tricks and questioning. These interventions are listed and shortly described in Appendix-4. Although these interventions seem quite exhaustive, we do not believe that the interventions found in theory capture all the intervening behavior of coaches in practice.

We believe, the picture of what coaching interventions are used should be completed. The design education literature offers direction in this respect by referring to and describing the art of improvisation as an important intervention coaching students in design programs. This improvisation intervention seems to fit the complex and unpredictable nature of coaching in general and of coaching students that work in CDCM in particular. Coaches need to improvise a lot responding at the moment to unexpected events and unpredictable situations. Coaches therefore, need to be adaptive teachers skilled in improvising while using existing repertoires of pedagogical patterns. In Appendix-4 we also provide an overview of improvisation techniques.

The overview of different interventions can be used as a checklist for coaches to look back and reflect on their coaching behavior. Perhaps a coach will discover tendencies in his coaching behavior and conclude that he uses some interventions quite often whereas others are hardly used. It might also be that it appears that the intended effect of a coaching intervention is frequently/now and then not realized. When coaches reflect on the use and usefulness of their coaching interventions it is important for them to bear in mind that each intervention has its own strengths and weaknesses. Depending on the style, preferences and strengths and weaknesses of the coach, the students’ needs and the aim of the intervention, a particular intervention can be chosen.

Guideline: Coaching will be more effective when teachers deliberately constrain the design process

Students working on CDCM have to deal with many different processes in parallel and have to make many decisions during the design process. Students need to learn to deal with this freedom, to make the right decisions and to manage their process. Setting the right constraints will guide students through the design process and lead them through a process of self-discovery, exploration, experimentation and active learning. Constraints can, for example, prevent students from following their instincts, start from one of the initial ideas and rush through the process by following this early idea. Depending on the stage of the design process and the activity to be undertaken the constraints get the shape. It is important for coaches to develop insight into the tendencies that students demonstrate when learning to design. Knowledge of these tendencies makes teachers alert to situations or moments in the design process where it needs to be a constraint. An example of constraints a teacher can set are: not to comment on the aesthetics of deliverables to guide students away from a focus on the intended final product (Sawyer, 2015). Another example might be that coaches do not provide specific answers because it prevents students from going to the process themselves.

## Literature

Adams, R. S., Daly, S. R., Mann, L. M., & Dall'Alba, G. (2011). Being a professional: Three lenses in design thinking, acting, and being. Design Studies, 32(6), 588-607.

Bruns, M., van Diggelen, M. R., & Wensveen, S. A. G. (2017). Study guide Industrial Design: the academic year 2017-2018.

van Diggelen, M., den Brok, P., & Beijaard, D. (2013). Teachers’ use of a self-assessment procedure: the role of criteria, standards, feedback and reflection. Teachers and Teaching, 19(2), 115-134.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. Journal of Engineering Education, 94(1), 103-120.

Hattie, J., & Timperley, H. (2007). The power of feedback. Review of educational research, 77(1), 81-112.

Lawson, B., & Dorst, K. (2013). Design expertise. Routledge.

Laurillard, D. (2013). Rethinking university teaching: A conversational framework for the effective use of learning technologies. Routledge.

Mercer, N. & Wegerif, R. (2003). Is ‘exploratory talk’ productive talk? In Daniels. HRJ., Edwards. A (Editors) (2003). Psychology and Education: a reader (pp 79-102). In (pp. 79-102). London: Routledge/Falmer

Tracey, M. W., & Hutchinson, A. (2013). Developing designer identity through reflection.

Watzlawick, P., Bavelas, J. B., & Jackson, D. D. (2011). Pragmatics of human communication: A study of interactional patterns, pathologies and paradoxes. WW Norton & Company.

## Appendix-1. Guidelines for coaching students that work on Complex Design Challenges of a Multidisciplinary Nature.

## Coaching during the whole project to ensure optimal learning.

### Different levels of learning in design-based learning.

#### Designing

The effectivity of coaching is enhanced when coaches actively undertake ‘expectation and learning-outcome-management’ and stimulate students’ to explicate learning experiences and outcomes from the start of the project to the assessments.

#### Design thinking & process

Learning to design will be more effective is coaches constantly stimulate students to articulate their underlying thinking, the rationale and how the process is unfolding when they are generating good work.

#### Self-regulation

Coaching will be more effective when teachers deliberately constrain the design process.

Coaching will be more effective when adhering to requirements of embedded formative assessment and the questions where students are, would like to go and how to get there are explored and answered.

#### Professional Engineering Identity Development

Coaching will be more effective if students are challenged to explore a teachers’ PEDI and (in the long run) develop insight into the range of existing design conceptualizations.

#### Vision

Coaching will be more effective if students are challenged to develop ideas on society, the discipline and the profession

## Prerequisites for effective coaching

Creating a safe and stimulating environment

Coaching will be more effective when dialogue amongst the project team is stimulated.

## A coaching approach

Coaching will be more effective when all stakeholders approach it as a continuous dialogue.

Coaching will be more effective when teachers deliberately pay attention to the communicational aspects of coaching.

Coaching will be more effective when a coach adequately applies conversation skills.

## A toolbox of interventions

Coaching will be more effective if teachers deliberately make use different coaching interventions.

Coaching will be more effective when teachers deliberately constrain the design process.

## Appendix-2. Competencies for coaching students that work on Complex Design Challenges of a Multidisciplinary Nature.

### Goal-directed coaching

The ability to actively undertake ‘expectation and learning-outcome-management’ and stimulate students’ to explicate learning experiences and outcomes from the start of the project to the assessments.

The ability to constantly stimulate students to articulate their underlying thinking, the rationale and how the process is unfolding when they are generating good work.

The ability to deliberately constrain the design process.

The ability to adhere to requirements of embedded formative assessment and the questions where students are, would like to go and how to get there are explored and answered.

The ability to support and/or challenge students to explore a teachers’ PEDI and (in the long run) develop insight into the range of existing design conceptualizations.

The ability to support and/or challenge students to develop ideas on society, the discipline and the profession

### Prerequisites for effective coaching

The ability to maintain a clear, explicit and steady professional identity;

The ability to create a safe and stimulating environment;

The ability to stimulate dialogue amongst the project team.

### A coaching approach

The ability to assure that all stakeholders approach coaching as a continuous dialogue.

The ability to deliberately pay attention to the communicational aspects of coaching.

The ability to adequately apply conversation skills.

A toolbox of interventions

The ability to deliberately make use different coaching interventions.

The ability to deliberately constrain the design process.

## Appendix-3. A self-assessment tool and Peer-assessment tool for coaching students that work on CDCM.

Four standards: 1. This aspect is not realized at all; 2. This aspect is hardly realized; 3. This aspect is almost realized, and 4. This aspect is fully realized.

## Coaching during the whole project to ensure optimal learning.

### Different levels of learning in design-based learning.

#### Designing

I actively undertake ‘expectation and learning-outcome-management’ and stimulate students’ to explicate learning experiences and outcomes from the start of the project to the assessments.

#### Design thinking & process

I constantly stimulate students to articulate their underlying thinking, the rationale and how the process is unfolding when they are generating good work.

#### Self-regulation

I deliberately constrain the design process.

I adhere to requirements of embedded formative assessment and the questions where students are, would like to go and how to get there are explored and answered.

#### Professional Engineering Identity Development

I challenge students to explore a teachers’ PEDI and (in the long run) develop insight into the range of existing design conceptualizations.

#### Vision

I challenge students to develop ideas on society, the discipline and the profession.

## Prerequisites for effective coaching

I create a safe and stimulating environment.

I stimulate dialogue amongst the project team.

## A coaching approach

I stimulate all stakeholders to approach coaching as a continuous dialogue.

I deliberately pay attention to the communicational aspects of coaching.

I adequately apply conversation skills.

## A toolbox of interventions

I deliberately make use different coaching interventions.

I deliberately constrain the design process.

## Appendix 4 – Coaching interventions

Instruction – in order to be effective, information provided to students’ needs to build on existing knowledge or a vivid image or recollection of an experience. Instruction is oftentimes used to provide the necessary knowledge for students. It is a teacher-directed intervention.

Scaffolding – this is a strategy a coach can use when the students need support and directive instruction. When working on this strategy, the teacher directs and structures the process. It is the opposite of challenging the students.

Modeling- acting as a role model, demonstrating as an expert how a task should be fulfilled. Often, the strategy of thinking aloud is mentioned when acting as a model. Thinking aloud helps students learn to reason like a designer.

Providing feedback – a coach is able to oversee the process students go through. In their coaching the coach can provide information to the students on where they are in their process, where they would like to go to or need to go to and how to get there.

Providing tips and tricks – it is often difficult for students to think of how to proceed and realize their intentions. If a coach provides tips and tricks, the students receive concrete input for moving forward. Oftentimes, it is best if students are offered with a range of options they can choose from.

Questioning – asking questions is one of the most important interventions in coaching. Questions can be formulated open and in a closed way and as a series of questions. Questions are per definition student-centered and can be helpful in making the student think. Questions can fulfill the same functions as feedback with the difference that a student needs to come up with the information when questioned and is provided with the information when feedback is given.