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# Designed by Engineers: An analysis of interactionaries with engineering students

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## ABSTRACT

*The aim of this study is to describe and analyze learning taking place in a collaborative design exercise involving engineering students. The students perform a time-constrained, open-ended, complex interaction design task, an "interactionary". A multimodal learning perspective is used. We have performed detailed analyses of video recordings of the engineering students, including classifying aspects of interaction. Our results show that the engineering students carry out and articulate their design work using a technology-centred approach and focus more on the function of their designs than on aspects of interaction. The engineering students mainly make use of ephemeral communication strategies (gestures and speech) rather than sketching in physical materials. We conclude that the interactionary may be an educational format that can help engineering students learn the messiness of design work. We further identify several constraints to the engineering students' design learning and propose useful interventions that a teacher could make during an interactionary. We especially emphasize interventions that help engineering students retain aspects of human-centered design throughout the design process. This study partially replicates a previous study which involved interaction design students.*

*Keywords: design, engineering education, interactionary, interaction design, learning design sequence, multimodal learning*



## INTRODUCTION

Engineering of today places a great amount of emphasis on innovative design, that is the design of artefacts that meet an increasingly selective market. Despite this, most engineering programs do not actively teach design processes. Engineering in general is often described as an analytical and structured way of thinking and problem solving which may stand in contrast to more expressive and "messy" ways of thinking and doing design. The collaborative creative process students engage in when designing is seldom straightforward, rather a shaking, bouncing, oscillating, circling, incremental progress (Sundholm, Artman, & Ramberg, 2004). Even though project courses let students 'do design', most project courses provide limited possibilities to support and coach learning in relation to collaborative design endeavours (Ramberg, Artman, & Karlgren, 2013; Sas, 2006).

We would emphasise a need for engineering education to better understand and to embrace collaborative design learning, learning processes which acknowledge haphazardness, serendipity and iterative creativity, and we propose the 'interactionary' as an educational format in which such learning can take place. The 'interactionary' is a highly time-constrained collaborative design assignment and has been tested on interaction design students (Ramberg, Artman, Karlberg, 2013). Ramberg et al. (2013, p. 54) conclude that the interactionaries" allow teachers to directly observe design considerations as they are formulated in real time and to discuss these with the participants".

## AIM

The aim is to describe and analyze the learning taking place in a collaborative design exercise. How do teams of engineering students embrace and perform a task of producing an interactive artifact? How do engineering students make use of aspects of interaction and how do they communicate with each other in order to describe how the artefact will behave? Finally, how can this be conceptualized in terms of learning?



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ENGINEERING DESIGN AND INTERACTION DESIGN

As a way of approaching design learning in engineering, researchers have studied the nature and character of engineering design processes (Howard et al., 2008). The standard way of conceptualising this process is as consisting of a number of qualitatively different phases which a designer team has to accomplish (e.g. Dubberly, 2004; Howard et al., 2008; Zoltowski, Oakes, & Cardella, 2012). Even though the recognition of the number of and the types of phases can vary between studies and contexts, such studies normally identify some sort of need phase, the specification of this problem/need, a conceptual design (possible technical solutions), an embodiment phase (the more concrete design of the technical solution), a phase of producing a more detailed design (the making of prototypes) and finally an implementation phase in which the products are launched on the market (Howard et al., 2008). These phases can be seen as necessary elements of any design process.

At the same time it has been pointed out that the design process is iterative, meaning that the designers can come back to certain phases when they see a need to revise or reject ideas generated in the process (e.g. Crismond & Adams, 2012; Sundholm et al., 2004). Also, in actual practice, the process is not always as straightforward and logically constructed as these phases might lead one to believe; real design processes are often messy and sometimes seem to exclude certain "necessary" phases. Further, the literature points to the fact that the "lenses" that form the designers' work can vary depending on the disciplinary origin of the designer (Daly et al., 2012). Approaches to design also vary with experience in the field. Studies show that senior designers not only produce higher quality designs, provide a more thorough problem scooping, gather more information, and consider more alternative solutions as compared to engineering students, but they also transition "more frequently between design steps" as compared to freshmen students (Atman, Chimka, Bursic, & Nachtmann, 1999, p. 131. C.f. Atman, Adams, Cardella, Turns, Mosborg, & Saleem, 2007, p. 359).

Research into the design process has until lately paid little attention to how the physical nature of the products being designed might change the more fundamental conditions of design. For example, the advent of digital systems has been described as having given rise to the evolution of a different type of material which can respond and act together with humans in a qualitatively new way as compared to most previous constructions and materials (Brennan, 1998; Thomassen & Ozcan, 2010). The designer and programmer give the digital material specific functionalities that make them fundamentally different as compared to non-digital (or analog) materials (Löwgren, 2004). The digital systems are *dynamically* changing as we use them, they *respond* to the user's request or *request* information from the user, they work in several *temporal* dimensions, and the design imposes some structural order on how the user might use the artifact. The tasks or the *context* where we use the computer system also affect, or define, the system (Gedenryd, 1998; Ozenc, Kim, Zimmerman, Oney, & Myers, 2010). These aspects of interaction are all of importance when designing interactive systems.

The digital design material poses new challenges to design learning as interaction becomes more focused (Buxton, 2007; Cross, 2004). An increased interest for disciplines such as Human-Computer Interaction and Interaction Design has followed (Thomassen & Ozcan, 2010). When designing interaction one needs to consider both the digital material (programming in digital matter) and the human (the objectives and prerequisites of using the artifact) perspective of an artifact/system. Digital materials accentuate the contrast between "technology-centered" as compared to "human-centered" designs (Krippendorff, 2006; Zoltowski et al., 2012). Learning human-centered digital design poses a challenge to engineering sciences which are often grounded in an objective and factual world-view, embracing a statistical and mathematical elaboration of a given problem, while interactive designs focus on qualitative and experience oriented argumentation (Löwgren, 2004).

As a way of enabling design learning in engineering education, some argue that new courses addressing aspects such as design processes and creativity should be included in the curriculum (Badran, 2007; Peslak, 2005). Others state the importance of arranging for students to gain critical experiences of design endeavours so that these experiences can challenge their conceptions of design (Karlgren & Ramberg, 2012; Zoltowski et al., 2012, p. 49). In



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any case the creative challenges of design persist as does the need for augmenting the process of teaching and learning creativity in design. Another problem with using models of design as a basis for design learning is that they are derived from conceptual discussions and indirect data such as results from interviews or questionnaires rather than from detailed analysis of design processes. Howard et al. (2008, p. 176) argue that "research must be conducted at lower levels of granularity to understand what detailed mechanisms lead to original and appropriate ideas being produced during the generation phases". Such research can provide important complementary knowledge into how students learn to design and how this learning can be embraced in education. In the following section we will look more closely into research on the design process at these levels of granularity.

## THE INTERACTIONARY AS A WAY TO LEARN INTERACTION DESIGN

The interactionary was initially conceptualized by Berkun (2001) as a pseudo game show type format that allows teams to work on the same design problem under extreme time-constraints live on stage, while being assessed by an audience. Berkun's original idea was to create an experiment in design education and invent a fun and innovative way of teaching interaction design. The initial attempts, however, were designed to take place on-stage during large conferences in the form of a contest. This allowed the dynamic intangibles of design in progress to be exposed to an audience who could watch the teams live and observe how they worked and interacted together. The design teams were allowed to organize their design work in any way they liked, and at the end of the design session, the winning team was nominated by a panel of judges.

The interactionary has been used in design education for some time. Ramberg et al. (2013) adapted it to fit an educational design setting and studied how students of interaction design approached and embraced a complex design assignment (to design a physical-twittering application) in short design sessions of approximately 26 minutes. Design material and instruction for the design task was provided. The participants could use whatever knowledge, experience or materials which were at hand in order to creatively explore the design space with the aim of presenting a prototype with an accompanying use-scenario. In order to further emphasize the interaction design learning, the instructions for the design task asked the students to pay special attention to aspects of interaction in their designs (dynamics, temporality, interactivity, sequentiality, and context-of-use).

The results from the study by Ramberg et al. (2013) include graphs presenting the frequency of instances where aspects of interaction are addressed in the discourse (Figure 1). The graphs thus present a representation of how well the students were able to use aspects of interaction in their design. As can be seen in Figure 1 both groups show peaks of occurrences (up to <20 aspects per minute) as well as short periods where no interaction aspects were addressed at all. The timeslots (Group 1: 13-16; Group 2; 18, 21) where no aspects of interaction were used coincided with situations where the students were involved in the physical design of the artefact. The groups differed in terms of numbers of members (Group 1 had two members and Group 2 had five members); however, the total frequency of interaction aspects was similar for both groups (Group 1 had a total of 229 aspects; Group 2 had a total of 201 aspects). Thus it seems that the total frequency of addressing aspects of interaction does not vary in terms of number of group members and may rather be a function of time available to speak and the familiarity and ability to enact and articulate the aspects of interaction in the context of the assignment.



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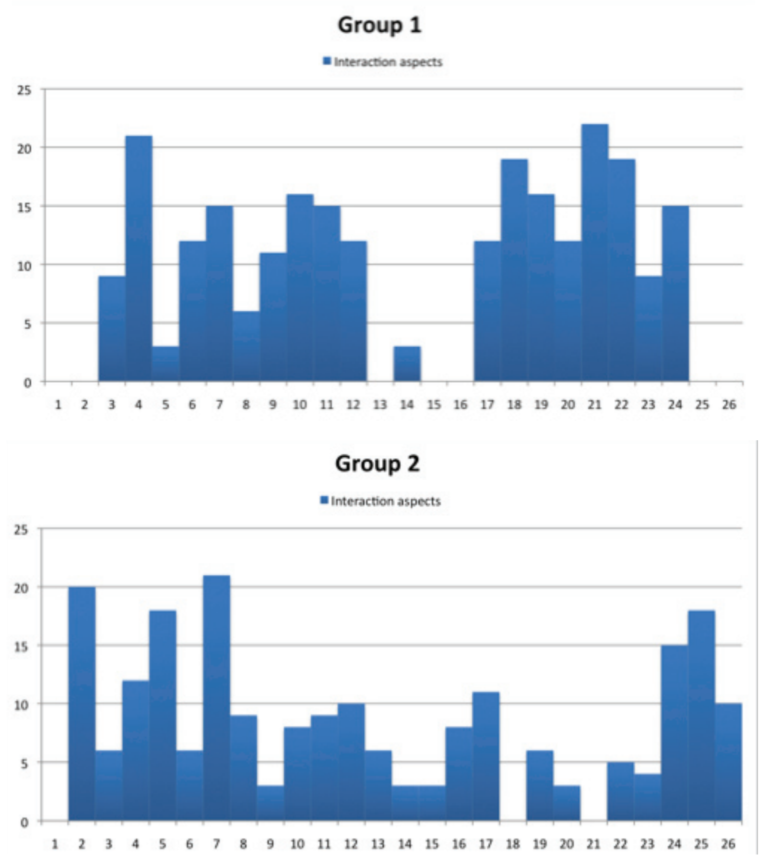


Figure 1: Number of cases of addressing aspects of interaction during the interactionaries minute by minute (from Ramberg et al, 2013, p. 39).

Ramberg et al. (2013) furthermore identified three phases of the design process; ideation, sketching and reflection/evaluation. The ideation phase consisted of interpreting the instructions and generating ideas to accomplish the goals articulated in the design-brief. This phase typically involved discussing and gesturing as a way to express how the design should behave. The sketching phase was more focused on how to make a physical and aesthetic representation of the prototype with less effort being put into the interactive details. The third phase focused on evaluating the designed artefact in terms of articulating a context-of-use scenario.



In the method section below we specify the setup for the interactionaries used in this study.

## METHOD

This study uses the same research design as Ramberg et al. (2013) in order to investigate how engineering students (chemistry) embrace and conduct a similar design assignment and to study the learning taking place when designing. The students in question had expertise in scent chemistry which undoubtedly includes aspects of interaction, but they had no previous experience of practical interactive design assignments or design teaching.

Two pairs of self-selected engineering students were presented with the task of designing an interactive artifact. The student pairs worked in a spacious room. The first pair (henceforth referred to as Group 1) consisted of two males, and the second pair (Group 2) consisted of a female and a male. The pairs in this study are referred to as groups for consistency with the terminology used in Ramberg et al. (2013) where groups were defined as two or more students. The design sessions took place on two separate occasions on the same day, one in the morning, and one in the afternoon.

At the start of each session, the participants received a document presenting a design-brief on 'Scent Chatting' as well as aspects of interaction relevant to the brief (the aspects of dynamics, temporality, interactivity, sequentiality, and context-of-use as defined below). The design-brief was formulated as a commission from a newly started company called iDOFT (iSCENT) where the task was to design an interactive scent device which would be controlled by events defined by the concept of scent-chatting. The design proposal was to include creating scents which could be adapted to different situations where scents were required for communication or dissemination of information. Furthermore, the brief stipulated that the device was not to be simply a unidirectional scent dispenser, but rather was to be coupled to events or to the mood, gestures or instructions of the users. We deliberately chose to define a so called "wicked problem", i.e., an unstructured problem that does not have one single solution in order to push the creative framing of the design task.



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The participants were informed that they had five minutes to read, pose questions to the teachers/researchers and discuss within the group. After that they had 30 minutes to both distribute tasks and design their proposal. Besides presenting the task and objective of the study, we did not intervene during the design sessions. During the presentation of the design task we emphasized that the participants should aim to come up with several design proposals and to have fun (being playful). They were asked to create design proposals including an artifact (i.e. a physical representation of the design proposal in a chosen material) and a use scenario with a special focus on interactive properties of the artifact and its use. The participants were further informed that they were to give a presentation of their final proposal to us. This presentation has not been included in the analysis made in this paper, only the design work carried out by the groups up to the point of presentation. The participants were also informed that the interactionaries could provide a good opportunity to practice collaborative design work, that participation was not compulsory and that the performance and results would not be formally assessed since the exercise was not part of their ordinary course work.

The design groups were provided with various design resources (whiteboard, clay, paper, plastic foil, scissors, Lego™, pencils, etc., see Figure 2) to use in their design work. The room was spacious enough to allow the students to diverge and work alone, as they deemed fit. The room was also equipped with a large whiteboard where they could sketch or present flow charts or other notations.

Figure 2. The design studio with examples of design resources.



The design sessions were video recorded from two different angles by the authors. Analyses of how frequently the participants addressed the various aspects of interaction during their design work were conducted in the same manner, with the same definitions and with the same protocol as reported in Ramberg et al. (2013). The different aspects were defined and rated relative to the following definitions:

- Dynamics: changes in either one of the interacting parts (system/human), e.g. happy/cry
- Temporality: temporal aspects of the interaction, e.g. now/tomorrow
- Interactivity: all aspects which assume active initiative or response, e.g. computer demands information
- Sequentiality: structured organization of certain processes, e.g. "this must be done before that"
- Context-of-use: aspects pertaining to the surrounding environment and practices, e.g. in the living room.

Three raters (the authors) independently observed the video. Each rater indexed in time when he interpreted that any of the five aspects of interaction were addressed by the students. After individual, independent ratings the raters discussed and aligned their ratings (both in terms of when in time and in terms of what aspect the students addressed). The alignment discussion of the video also included a qualitative analysis of the content (e.g. reacting to smells, choosing a scent, etc.) and mode of expression (e.g. gesture, pointing, sketching, etc.). Final inter-rater reliability Rxy-coefficients were 65% (Group 1) and 79% (Group 2). These analyses (presented in the results section) provided a systematic inventory of the ideas related to interaction design, without rating the quality of the contributions. The video data was also analyzed using an interaction analysis approach (Jordan & Henderson, 1995) to entail a better understanding of the participants' enactment of the different aspects of interaction (the five aspects presented earlier).



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Transformation as a pivotal characteristic for learning processes has been suggested in several theories, i.e. developmental psychology (Vygotsky, 1986), activity theory (Engeström, 1987), distributed cognitions (Salomon, 1993; Hutchins, 1995), and recently in designs for learning (Selander, 2008). These different theories all have slightly different contexts for discussing and defining transformation; however, the essence comprises changes of meaning in the communicative process as well as changes inscribed in the medias (movies, books, imagery, etc.) and modes (spoken language, sound, etc.) of communication, leading to an increased capacity for participants to use signs and engage meaningfully in a situation (Selander, 2008, p. 12). This focus requires theories that address the use of non-linguistic elements in instruction and in student performances coined as multimodality of communicative action:

*Multimodality attends to meaning as it is made through the situated configurations across image, gesture, gaze, body posture, sound, writing, music, speech, and so on. From a multimodal perspective, image, action, and so forth are referred to as modes, as organized sets of semiotic resources for meaning making.* (Jewitt, 2008, p. 246).

Multimodal research has mostly been directed towards understanding the increasingly multimodal character of today's communicative practices. A key example is given by illustrating a student studying a course textbook as compared to the same student studying a course website with interactive features. While the textbook normally tells a linear story, from page one to the end, leaving little room for the student to alter that story, the possible meanings constructed through the encounter of the student with an interactive website are much more unpredictable. For example, out of ten possible links on the first page, and ten more on each consecutive page and so on... one can quickly see that the possible texts to be constructed become almost infinite. Furthermore, the student may be able to add to the content by web forums, uploading tasks, etc. Thus, the student can be engaged as a co-constructor ('co-author') of the course. This also changes the traditional roles of teacher and student (Jewitt, 2008, p. 259), and raises the need to better understand these new ways of creating meaning:



*Through understanding how people select modal resources, multimodality emphasizes the dynamic character of meaning making toward an idea of change and design.* (Jewitt, 2008, p. 263).

Selander and colleagues have suggested a theoretical framework called Learning Design Sequences (LDS) (Selander, 2008; Selander & Kress, 2010). The framework is based on an institutionalised perspective and focuses on how actors connect and orchestrate many multimodal transformations in order to form a "representation", that is the "learning outcome". This in turn can be subjected to new transformations (based on for example feedback from the teachers or peers) in order to be developed further.

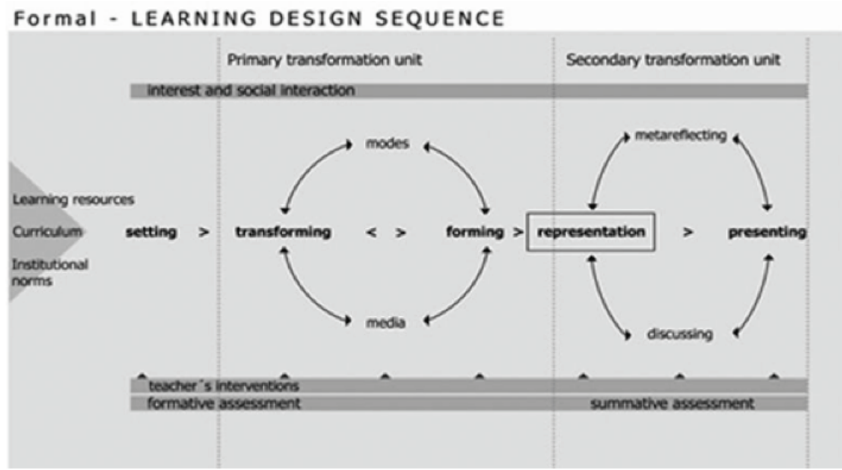


Figure 3: The Formal Learning Design Sequence Model (Selander, 2008).

Figure 3 presents a three stage sequence for learning of a formal Learning Design Sequence (LDS). The first stage is defined by the curriculum and institutional norms as well as prepared learning resources (text books, work material, particular instruction) which together with the specific physical space for learning form the setting. The second and third stages are conceived of as "transformation units", i.e. instructional units where students perform delimited assignments involving transformations of modes and/or media in the external representations students work with. The primary



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transformation unit is the stage in which the students actively and concretely work with orchestrating modes and media in order to fulfill the task which through several transformations should end up as some form of representation. The transformations are the changes in media and modes which encompass the capacity, depth or creative interpretation in learning. The representation is then used as the input for the secondary transformation unit where the learning outcomes from the primary transformation unit are put in perspective and discussed. In this study we will concentrate on the primary transformation unit.

The use of different media to express and represent modes is an important part of the framework which includes all forms of semiotic and bodily expressions. This makes it specifically appropriate for creative work since much creative work includes enactments and gestures as well as dramatization (see Arvola & Artman, 2007 and Tholander et al. 2008 for other examples of creative design work). The LDS framework will in this study serve to facilitate the analyses of all forms of semiotic and bodily expressions of aspects of interaction and their transformations. We will also return to the LDS theory in the discussion to further elaborate on the interactionary as a LDS.

## RESULTS

In our study we focus on the primary transformation unit. Below we present the design work done by the two student groups. We present the data chronologically and focus on certain sequences which formed their final design. After this will follow a more quantitative analysis of the design work.

## GROUP 1: ISCENTER

Group 1 begins their session by presenting and discussing a variety of scent design possibilities including scent-designed clothes, perspiration, body odor, pheromones, and scent dissemination in shopping malls. This sequence is characterized by frequent references to the aspect of dynamics when elaborating on the design possibilities. An example is shown in Figure 4. Here, the participant on the left introduces the problem of sweating and proposes using scents to hide or eliminate unpleasant smells in the manner of a deodorant. This proposal is initially accepted by the other participant who mirrors the gesture and elaborates on the proposal. A symbolic gesture is thus used conveying the understanding of the proposal. This demonstrates how aspects of a design can be shared between participants in other ways than for example a "yes" or a nod as a response to a design statement.

Figure 4: Example of a sweating gesture and a mirroring gesture.

Then, after having re-read the instructions and the design-brief, they realize that they need to put their ideas into a communication context. They begin discussing another contemporary technology, namely smartphones, and the idea of a new encasement with galvanic sensors which could sense temperature or moisture in the palm of the user. The general idea was that the smartphone would be able to communicate a certain user's emotional state by relevant scents.

In Figure 5, the participant in the dark jumper refers back to the topic of perspiration described above and presents the idea of how a smart-phone can measure palm temperature through a sensor. At the time of the current study, smart-phones are an important and permeating form of technology with short text-messages (and chats) being very popular forms of communication. The idea presented is a form of automatic chat where the smart-phone measures skin temperature and sends some form of scent to the receiver. The idea resembles the design-brief idea of scent-chatting to a high degree. The other participant does not share the enthusiasm of his





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design partner even though he shows his understanding of the idea at first by mirroring the hand gesture. Hesitantly and politely he points out technical limitations to including all the scents in the smartphone, and then incorporates the idea into a conic box to have in the living room and illustrates this box through his gestures (Figure 5). Thus, rather than rejecting the idea of a smart-phone sensor he introduces a different form of technology which resembles another common and contemporary technology, i.e. a console connected to a TV. Both participants get inspired by this idea. The context-of-use is now more of a living room device than a personal device. Moreover, the new idea of a larger and more centrally located device solves the technical problem of how to contain all the scents in the device. Both participants approach the idea with enthusiasm. In this sequence, the participants refer to the aspects of dynamics, sequentiality and context-of-use. This ideation phase was also accompanied by an extensive use of gesture by both participants illustrating and strengthening the group's conceptualization.

Figure 5: Example of the development of an ideation moving from smartphone to the scent console (iScenter).

When it is clear that the idea of a box is accepted by both participants, one of the participants starts to sketch the box on paper and at the same time articulates different functions. The former idea of the encasement of a smartphone is incorporated in the sketch. The other participant discusses and accentuates these thoughts. The sketch anchors and re-contextualizes the ideas in a new mode. The physical sketched object becomes "real" - a media that incorporates signs. "This is the box!" he says and points to the sketch. The other participant also points at the sketch as it becomes more mature. The sketch then becomes the center of the discussion. The name of the box becomes iScenter as it is in the center. Quite obviously the students are very satisfied with this clever name.

When sketching it is mainly the participant with the checkered jumper who holds the pen, while the one in the striped jumper engages in the sketch by pointing and discussing (Figure 6). At this stage in the process they are mainly fine-tuning the proposal and describing how different devices are connected (smartphone, game-console, computer). The participant in the striped jumper is also thinking beyond the system's functionalities and discusses how to organize a project in terms of competences as well as how a user perceives and associate scents. The sketching again makes their design work focused and practical rather than associative and creative.

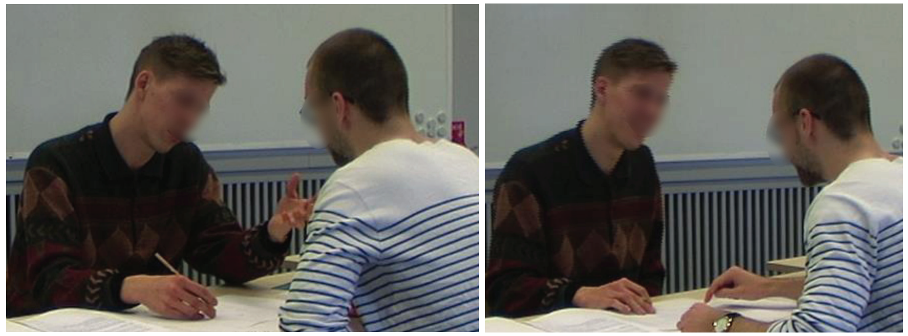

Figure 6: Sketching as a collaborative activity.

At the very end they return to the design-brief and the instructions to check that they have covered all goals and aspects of interaction. However, they do not detail a use-scenario and hence focus less on the aspect context-of-use.

### GROUP 2: SCENTBOX

Group 2 begins the session concentrating rather directly on the chat feature of the design-brief. They start to discuss how one would be able to communicate by way of sending strong scent messages which are acted out in gestures. The proposed communication is relatively straightforward with simple messages which are easily conveyable. In the first example, illustrated in Figure 7, the female participant proposes how scent chatting could



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take place when the message “I like you” (her hands pushing away illustrating sending the message) is responded to by a strong scent message (her arms flying backwards from the strong scent conveying being blown away). Thus the same designer is playing two different roles during this enactment. In contrast to Group 1, the main aspect used here by Group 2 is interactivity with some reference to sequentiality and temporality.

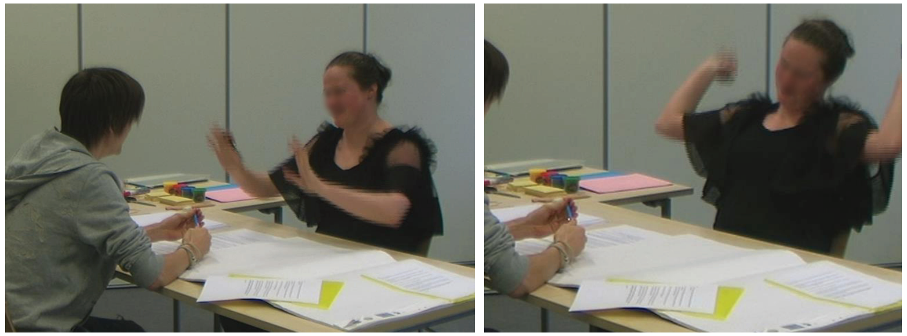

Figure 7: Example of “scent chatting” exemplified by gestures.

This proposal was initially accepted by the other participant who elaborated it with regard to “distance chatting”. However, the topic of distance chatting was temporarily abandoned being rejected in favor of a discussion about how to create different scents.

A proposal which is rejected immediately is illustrated in Figure 8. Here the female participant suggests using gestures to indicate specific scents that should be transmitted and where specially designed infrared camera gesture recognition would trigger the appropriate scent. The other participant rejects this idea with the argument that gesture recognition is already well-developed and not novel (=not appropriate for their design proposal).



Figure 8: Example of proposed gestures for triggering scents.

This straightforward rejection does not seem to allow for more complex interactions between the prospective users where messages need to be interpreted and related to certain contextual factors such as the relationships between the users. The female participant brings up context, and the male agrees but complements the situation with a computerized automatic solution. We interpret this to involve a further simplification of the digital communication process between the prospective users. The participants continue discussing the idea of communication over distance, but then they abruptly abandon the focus on communication and turn to the problem of how to develop different scents. This in turn, by a quick shift of focus to chemical boxes for children, leads to the name for their proposal “scentbox”.

They start to present ideas of how the scentbox would work in terms of functions as well as its volume. Even though the discussion touches upon context-of-use aspects it becomes more of a concern of how to construct the box in order to be able to send scents. The communication feature is left for a while in favour of how and if users should be able to define their own scents and sequences of scents. However, they do return to the communication feature as the female participant jokingly presents how someone sends a bad smell (a fart) over distance. This is in correspondence with the above scenario but with quite the opposite intent and semantics.

As described above, this group had a series of rejected ideas mainly as a result of one of the participants proposing new ideas which the other one would reject. As a consequence they return to the instructions and discuss each aspect presented in the design-brief. As they read the instructions out



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loud accompanied by pointing (see Figure 9) the participant on the right starts to grab the design materials on the table beside them. She hands over a jar of clay to the other participant and after awhile he opens it up and they both laugh. He then quite sentimentally comments on the scent of clay. Both participants start sniffing the scent of the clay-jars. Thus in multimodal terms they are using the clay not only as a design material but also as an inspiration.

Figure 9: The clay-jars are used as an inspiring design material, which helps them restart the idea creation.

After they have smelled the clay, she proposes some gestures that the computer would be able to pick up. Again the male participant is a bit reluctant and trivialises the ease at which a computer is able to recognize gestures - he is aiming at something more beyond (his idea of) contemporary design. This time rather than accepting the weak form of rejection, the female participant quickly reaches over toward the other design materials and begins to tinker with the lego-blocks. The design material causes the participants to focus on scents and the instructions lead them to focus on the design objective - that is digital communication and scent-chatting. They discuss how the user is to interact with the system. Furthermore, they now start discussing a scent-system that is analogous to a surround-system of audio speakers. Using the lego-blocks, they conceptualize how the scent-speakers could be spatially organized and discuss how different scent-speakers will send out various scents differing in strength. The scentbox with perfumes becomes central to their design idea.



Given ideation in terms of their design proposal, the participants must continue on and transfer this idea into a representation which is more stable and concrete. Sketching in various ways (pen-paper sketching, clay-sketching, lego, etc.) is a common way to do that. Sketching introduces another form of focus-shift. From being conceptually creative, focus is now on being practical, concentrating on the form of the artifact and being constrained in terms of innovation. This shift in mode was also seen in Group 1 and with similar consequences.

The design materials (clay, legos) helped the participants focus on the agreement of the basis of the design proposal. The focus is now on the layout and how the scents are presented to the user. The sketching is done by a quite simple pen-paper sketch which presents a design showing that the scent-box is connected to a computer and that the scent-speakers are organized within a living room (see sketch illustration in Figure 10). The participants also introduce the game-consoles as a way of standardizing the scents that could be presented by the system (some other ideas are also presented as a customer-service function). Spatially ordered lego-blocks are then attached to the pen-paper sketch. Tinkering with the lego-blocks makes the participants concentrate on how the user receives scents, and they partially abandon the idea of how to interact with the computer by gestures. The sketching activity (but also that time was running out) thus helps them to change perspective and make a transition, from interaction to reception and how the system would help the user experience changes in intensity in the scents presented. Later on in their presentation of the proposal they return to how the user interacts with the system.



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Figure 10: The participants start to sketch a design proposal by using lego-blocks and pen and paper.

## SUMMARY OF THE PRIMARY TRANSFORMATION

The final design proposal is quite similar in both groups. Both groups present some kind of box with different scents/perfumes to be connected to a TV and/or computer and game console. However, their process and engagement to this proposal diverge. Generally Group 1's teamwork is characterized by a greater acceptance and inclusion of former ideas than Group 2. The participants in Group 1 tend not to reject certain ideas but rather to include them in the development of the proposal. In Group 2 one of the participants simplifies much of the technological features.

## QUANTITATIVE ANALYSES

Figure 11 presents the frequency of aspects used during the primary transformation unit (the design work done by the groups) in a similar manner as in Ramberg et al. (2013), see Figure 1. In Figure 11 the assessed frequency of interaction aspects enacted and articulated during the primary transformation unit is presented. Although the analyses of the groups' design processes registered approximately as many instances of interaction aspects, these aspects were spread out differently in the two group sessions. While Group 1 presented a more aligned and dynamic process where different solutions were discussed and elaborated on, Group 2 decided on a rough design proposal quite early on, and elaborated on different ideas of the design in a more scattered manner. In Group 1, there is a main peak of using interaction aspects which culminates at 17 minutes into the session (a sequence with many contributions, roughly equal to an extra creative part of the session, see below). This main peak corresponds to the development of the key solution by Group 1. Group 2, on the other hand, shows a pattern of recurring scattered peaks in the diagram. These scattered peaks signify to our understanding more stand-alone ideas which are not developed but rather replaced by new and slightly different proposals.

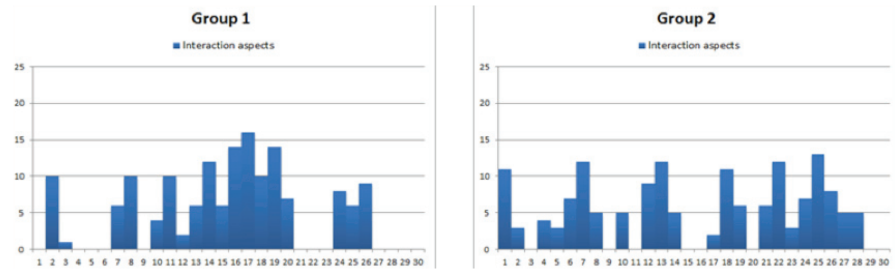


Figure 11: Number of cases of addressing aspects of interaction during the interactionaries minute by minute (Group1=iScenter; Group2=scentbox).

The relative frequency of the aspects is presented in table 1. It is noticeable that Group 1 focuses on aspects adhering to dynamics while Group 2 focuses more on aspects adhering to interactivity.

| | Group 1(iScenter) | Group 2 (Scentbox) |
|---|---|---|
| Dynamics | 67 | 22 |
| Temporality | 6 | 18 |
| Interactivity | 28 | 73 |
| Sequentiality | 33 | 23 |
| Context-of-use | 17 | 18 |
| *Sum:* | *151* | *154* |

Table 1. The frequency of the aspects of interaction addressed by the engineering students.





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## DISCUSSION AND CONCLUDING REMARKS

### ENGINEERING STUDENTS DOING INTERACTION DESIGN

It is remarkable that both groups in this interactionary came up with similar ideas i.e. a box containing scents which is connected to a device (TV, game console). This is a general type of device which can be used in different situations such as gaming, watching TV, chatting, etc. Relating to contemporary interactive systems, this is a conceivable device (similar products have been presented on the market). The general character of the device can be a result of the design processes, such as less focus on context-of-use with more attention being paid to technical features relating to dynamics and interaction. Thus, in relation to the idea in the design-brief, i.e. scent-chatting, both groups were more focused on scents, i.e. the output of scents, in their final designs than on the chatting part. This is not to say that the chatting feature of scents was ignored, but rather that these aspects fell into the background as the actual designs formed. In other terms one can say that while some of the design work during the ideation phase was "human centered", the final phase of the design clearly became "technology centered", not designing for the purpose of chatting, but for the purpose of designing a digital device that can transform a broad range of different inputs to a system into scent. In a sense the students effectively avoided the task of designing interaction and thus missed a complex or unusual learning opportunity. However, it might be something in the task and in the design-brief that made the students come up with similar ideas. It may also be due to the time-pressure inherent in the interactionary format, or even a conservative mindset of the students/designers. Still, they were generally true to the instructions. They returned to the instructions and matched what they did with the instructions.

There are clearly some differences between the chemical engineering students in this interactionary and interaction design students presented in Ramberg et al. (2013). Compared to the graphs in Ramberg et al. (2013), see Figure 1, we can see that the engineering students use interaction aspects more sparsely. In exact numbers Group 1 used 151 aspects in total and Group 2 used 154 aspects (see table 1). That is approximately one fourth fewer in number compared to the interaction design students in Ramberg et al. (2013) even though the engineering students had 4 minutes more time at their disposal. Noteworthy is also that the single highest peak for the engineering students represents only 16 interaction aspects per minute compared to several minutes where more than 20 instances are recorded for the interaction design students (see figures 11 and 1 respectively). The use of different raters in the two studies as well as using different design assignments can of course have affected the ratings, in either way. However, one of the raters was the same in both studies, which makes the comparison somewhat more reliable than would otherwise have been the case. Given the fairly large differences between the two studies we would say that it seems likely that the engineering students did not utilize the aspects of interaction to the same degree as interaction design students. But this needs further study in order to verify if this is an indication of more general differences between engineering and design students and how this might affect the designs produced as well as learning opportunities.

We could also see that the students in our study did not make much use of the different design materials in contrast to the students in the study of Ramberg et al. (2013). The students in our study mainly used paper and pencil. Apart from some minor clay use in the second group (scentbox) which was mainly used as a scent(!) and some small figures which were put on the paper sketch, they did not use any of the other design materials provided. The whiteboard was used during the presentation by the first group. This is a difference compared both to expectations and to the interaction design students who all made more extensive use of the clay, lego and other tinkering materials. Compared to the design students, function is more focused on by the chemical engineering students than is appearance. This is probably a construct of the competence of the individual participants. If one has chosen a design education it might be that one is more competent, or interested in, how things work in use as well as how they appear in terms of aesthetics rather than in the technical details of their function. Thus, if learning is seen as an increased capacity to use signs and elaborate on these in different media and modes, this study points to potential benefits in increasing the capacity of engineering education students to use a broader range of different modes and media in their design process.





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A similar result to Ramberg et al. (2013) concerns the sketching phase and the sharp decline in the use of aspects of interaction as the design work becomes focused on appearance. As already noted in relation to the engineering students, the shift in media gives a shift in design focus from human centered to technology centered, and where interactive features are downplayed. At first sight this seems to contradict the fundamental assumption to multimodal theories of learning, i.e. a belief that learning is about an increased capacity to use signs and elaborate on these in different media and modes. What if a certain mode and media in a certain context actually impairs the students' abilities to fruitfully engage in a certain task? As was mentioned in the beginning of this paper, studies show that senior designers transition "more frequently between design steps" as compared to freshmen students (Atman et al., 1999, p. 131). That senior designers transition more frequently between design steps indicates that they are aware of the constraints being imposed in the transition between design steps and are not impaired in the same way by the such transitions as seems to be the case with students. This means that the ability to use modes and medias also means an ability to know of the limitations of certain modes and media in certain contexts and stages of the design process.

In relation to the interactionary as an educational method, which was emphasised by Ramberg et al. (2013), we have also found that the interactionaries engage the students as well as frame their design space in terms of ideas and goals. However, the aspects of interaction, such as those presented in this study, may not easily translate between different student populations. Engineering students seem to have a more technological preference as well as being more accustomed to structured design tasks, often framed as solutions to certain problems. The interactionaries put more emphasis on the creative aspects of meeting unknown and unforeseen objectives. Still, we think that interactionaries can be an important step towards making engineering students more aware and responsive towards open-ended design tasks which put the human in the center of technical development. To do this one might have to put a stronger emphasis on the aspect of context-of-use.



The interactionary may in any event be an educational format that can help engineering students to understand and learn the messiness of design work (Badran, 2007; Crismond & Adams, 2012; Peslak, 2005). The interactionary as such forces the students to focus on the design-brief with its constraints, while at the same time making use of both formal, curriculum-based, and informal, experience-based notations of knowledge.

## THE INTERACTIONARY AS A LEARNING DESIGN SEQUENCE

Taking the multimodal perspective of Learning Design Sequences-theory, the design-brief together with the design resources provide the "setting" of a LDS. It is important that these provide both constraints and room for creativity. During the primary-transformation unit, within LDS, the students may orchestrate between several modes and media during different phases in order to improvise an embodiment of the artifacts. As interactionaries are severely time-constrained the students cannot ponder on all possible co-constructs of creations; this helps them stay in focus. As in the study by Ramberg et al. (2013, p. 54), we found that several promising ideas did not make it into the physical representation phase. Furthermore, the time-constrained nature of the interactionaries may not allow students to detail a prototype nor enter phases of implementations (Howard et al., 2008). But given these constraints to possible design-learning, a design teacher could then, during the first transformation unit, focus on providing suitable interventions regarding the students' uses of the interactive aspects, so that the students can enhance their abilities to do design (cf. Ramberg et al., 2013). Given the results from this study, such interventions can highlight the need to address "context-of-use", or, when reaching the embodiment phase in their design (when sketching or using clay/other resources), to make them aware of the fact that these transitions tend to reduce the design endeavour to appearance or function, and thus help them to retain aspects of human-centered design throughout the design process. And even more, this could be expanded to include transdisciplinary collaboration, involving scent chemists/engineers (in this case) to allow for constructive feedback also regarding the more technological/scientific prospects of the interactionary.



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