TEACHING STUDENTS TO APPLY MULTIPLE PHYSICAL MODELING METHODS

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ABSTRACT

Design students should be able to explore a variety of shapes before elaborating one particular shape. Current modelling courses don’t address this issue. We developed the course Rapid Modelling, which teaches students to explore multiple shape models in a short time, applying different methods and materials. The course contains four parts: modelling basic shape features, making multiple shape variants in a short time, applying multiple modelling methods and choosing an appropriate method. After the course, students were able to apply different methods to make expressive models in less than 15 minutes. Questionnaires revealed that many students expect to apply the new learned methods in future projects. Indeed, in their next project, we saw them use many different methods, including newly learned ones. Students were positive about paper, Rhino, SolidWorks, plasticine and natural clay. In particular Rhino was expected to be used often in the future. We think the introductory course they followed, had inspired them. We suggest having a Rhino course in the Bachelor, not only as an elective in the Master. The course Rapid Modelling makes students aware of the need and the possibilities of making quick models for exploration. Students who followed the course can be expected to explore more and quicker and come up with more innovative results.

KEYWORDS

Shape modelling, idea generation, early prototyping, physical models

1. INTRODUCTION

To make innovative designs, it is good to explore a wide range of possibilities. Therefore, the early phases of design are characterized by exploration, creativity, looking to generated ideas, generating new ones, watching them, reflecting on them and varying them at the same time. These activities can follow each other quickly and for stimulating the creativity and it is important that the working rhythm is not slowed down by activities that are difficult and require a lot of attention of the user [4, 20, 28]. Elaborating details can slow down the idea generation and can, in general, better be postponed to a later phase, after the possible solutions are sufficiently explored [14, 25]. Once an idea is elaborated and detailed out, it is more difficult for designer to consider alternatives. Thus, it is better to generate many ideas first and do the detailing later, after a first selection of best ideas is done. However, it is easy for students to start making a CAD model and work it out, for several reasons. First, most students carry their laptop the whole day, so it is easy for them to start making a CAD model. Besides, CAD programs, in general, require rather concrete input [28]. It is not easy to make a vague CAD

Figure 1  Several methods for early prototyping. From left to right: natural clay, foam, wire, plasticine and paper.
model, like you make some scribbles on sketch paper. This makes it easy for students to start early with a CAD model, and keep on elaborating it, without sufficiently thinking about possible alternatives. Therefore, although CAD software has many benefits, also for exploring the spatial configuration of objects [19], it is often best to start with conventional methods [12]. The different virtual and physical modelling methods all have their particular characteristics. It is good to know these characteristics and deploy the method that fits best in the particular situation. Kuutti [13] mentions a number of advantages of physical models: they have size, weight and material and they can be touched, and manipulated directly, they can serve ergonomic evaluation and support a discussion while all participants see and manipulate the same model. They elicit engagement and allow people to “think with their hands” [8, 20]. They help to explain spatial relations [10]. The use of physical representations can help to build common ground in teams [5].

Apart from the fact that students easily tend to start modelling on their laptop, also in education there is less focus on traditional modelling methods. Because of all kinds of new developments, the curriculum is under pressure. But would be a pity if, for these reasons, students would not sufficiently learn to explore possibilities, but rapidly fixate on one particular solution, while possibly, much better, or more original solutions exist.

Furthermore, the elaboration of a concept reinforces the tendency to stick to that concept, even if problems emerge. The more time is spent on a concept, the more difficult it is for its designer to drop it and start anew. However, making a fresh concept is easier if it concerns simple models that can be generated within a few minutes. Such models stimulate the designers to explore a wide area of possible solutions and, during the generation of small models, get new ideas again. The benefit remains in later phases of the design project. If, during the elaboration of a concept, a problem merges, the designer easy remembers alternative solutions. Moreover, these are solutions with which the designer already familiarized herself, so the threshold to change is not so high.

If we want students to make many quick models, they should have the necessary knowledge, skills and attitude. If they don’t know particular modelling methods, or they don't remember them, it is not very likely that they will apply them. If they are not very skilled in a modelling method, it may be difficult for them to get satisfactory results and they may not like to use that method. Finally, they need sufficient knowledge of the design process to take the right attitude: open for alternatives, as for the concept as well as for the design process. This openness means that, during the generation of ideas and models, they keep observing the result, reflect on it and, based on their reflections, generate new ideas. Besides, they need to be aware that it depends on the situation which modelling method is most appropriate. With that, it is important that the designer will be inspired. Inspiration depends very much on someone’s personality. So, it belongs to the attitude of the student that he is aware of which methods inspire him best and which ones work most pleasingly for him. So the student should not only reflect on the concept in the making, but also on his way of working and the choices of his approach [22].

A prototype makes visible and tangible what the characteristics of a concept are. This helps the designer to evaluate the concept properly and improve his mental model of the concept [27]. In many cases, spatial models give insights that sketches or CAD models don’t [15], and also hand-based interaction has advantages [6]. Stones [24] shows that some types of solutions occur less frequently if only digital media are used. Lim [30] defines a prototype as a "manifestation that, in its most economic form, will filter the qualities in which a designer is interested". He also explains that the "goodness" of a prototype depends on the purpose for which it is made. Our focus is on generating ideas for a product’s appearance, its spatial structure and its physical interaction. For this purpose, simple models are sufficient and economic. For prototypes at the end phases of the design process, the product as a whole will be evaluated. This requires much more complete and elaborated prototypes than those that are used during ideation and conceptualization.

Elaborated prototypes enable the designer to improve the concept before expenses are made for manufacturing the product [11]. Römer [17] shows that the generation and evaluation of physical models saved them work later. In general, expenses for manufacturing are high, in particular if new production machines must be purchased. But also, when a test series is made by a production company, the price per product will be high.

Prototypes enable the designer to improve the concept before elaborating it. The further a concept
will be elaborated, the more effort and time will be spent on it. However, if early prototypes (Figure 1) make clear that changes are required, it will cost less time and effort to implement the change. This is illustrated in the left part of Figure 2. The right part of this figure shows that the design cost also depends on the type of modelling method that will be applied. For less than one euro one can make a small model of paper or natural clay. Models of plasticine or foam are still cheap, but for styling clay and 3D-prints, several tens of euros is not much, and a full functional prototype may cost hundreds or even thousands. The mentioned amounts are just examples. The real expenses depend on multiple factors, such as size and complexity of the concept. So, which modelling method is best, depends very much on the design phase. Also if an advanced prototype is made, it is good to start with simple modelling technologies, such as clay and foam modelling (Figure 3). Apart from the expenses, there is another reason. Rough clay and foam models, just as sketches, leave more space for reinterpretation. In a rough model, the designer can see what he intended, but he can also see something different in it. Won [28] call this the shift from ‘seeing’ to ‘seeing as’. Yang [29] even found that less detailed prototypes, finally, lead to better final products.

2. METHOD

To solve the above problems, we want that students learn to perform a rich exploration of possibilities, rather than bogging down into details too early. We want students to learn to evaluate ideas early, and lower their thresholds for making adaptations and variations. If they are aware that several variants of an idea can be made in a few minutes, they will do more exploration instead of directly sticking to one of the first ideas. Physical materials like clay and foam enable the designer to make a quick model, without the need to generate a complex CAD model first. However, some CAD modellers, such as Rhino [16], can also have a function during conceptual design, because they allow working with models that are not yet completely correctly and exactly defined. The students should be able to generate shape models rapidly, to prevent that their creative flow of thoughts is slowed down or their minds gets distracted to other business. The focus of shape ideation must be on finding new shapes, not on how to model them. Because of that, the modelling activity should be easy for the student. This implies the student should know which modelling method is best to express a particular shape feature and the student should be sufficiently skilled to model the feature without much conscious thinking. Students should come up with shape variants themselves, there are no examples that should be copied, because creating a shape require a different mind focus than copying one. Students should be aware that models can be generated from different materials. They should know that the different materials have their individual characteristics and they should be able to choose an appropriate material, depending on the situation (e.g. availability of space, tools, time, and material), the type of shape (e.g. compact or tiny, large or small, prismatic or organic) and the goal of the model (e.g. inspiration, discussion, test or presentation). For some shapes, it may be better to use multiple materials (e.g. if a shape contains solid and thin parts, or if particular elements should stand out).

Just knowing different modelling methods is not enough. The students should also experience how it feels to work with the different methods, how easy or difficult it is to achieve a desired result, and how satisfying the final result will be. They should be able to make expressive models, not insignificant, characterless chunks of clay. For that, they should be able to make some basic shape features. To make
expressive models, students should be able to make clear edges (sharp or rounded, but not crookedly and frayed) and clear surfaces (flat or curved, but not bumpy). They should be able to express clear sub shapes, with sharp transitions or smoothly blending, but no unidentifiable lumps. Assembled parts should not fall apart and bended parts should not break. The model should contain sufficient detail to express its character.

Making scale models is convenient because it can be done rapidly and the models can easily be turned and manipulated and watched from different points of view. However, seeing a real sized product is an experience that differs from looking to a small model. There will be different details that attract your attention. Besides, for the appreciation of particular shape elements, also size matters. Students should be aware of that aspect.

In many cases, a longer time of experience is required to be able to properly judge what is possible and to choose the best way to realize it. Therefore, choosing an appropriate material is an activity should be taught after the students have at least some knowledge and experience with the individual materials. Being aware of the importance of exploring, the students will adopt a proper attitude and be prepared to spend sufficient time on investigating variations and alternative solutions.

Based on the above, we define the following learning goals for the course:
1. Students should be able to make multiple shape models in a short time
2. Students need to know different methods for making shape models and be able to apply them
3. Students need to know the different characteristics of individual methods and be able to choose an appropriate method for their situation
4. Students need to be able to model basic shape features in an expressive way
5. Students should know the effects of differences in scale

To our best knowledge, courses with these learning objectives don't exist. Modelling courses for CAD can easily be found [31], but few publications about physical modelling courses can be found. Several announcement of physical modelling courses exist [32], however, in general these courses are meant for artists or hobbyists and their learning objectives and teaching methods are not clearly described. Akleman [33] does give a detailed description, but still this course is for artist, not for ideating product designers. In particular, the objective making multiple models in a short time does not occur in published courses. So we had to develop a new course, based on the learning goals above. The course is developed as a part of the minor Advanced Prototyping [7]. In this minor, bachelor students learn advances methods to generate prototypes. They get acquainted with a wide range of prototyping technologies and they have to apply many of them. The minor contains projects in which the students have to make their personal designs and prototype them. In this way, they learn to choose independently which technologies are appropriate for their concepts and how they can be applied best.

The course is developing in an evolutionary way. It started three years ago. After each year the course has been given, the results are evaluated and adaptations are made. It started as a course on clay modelling, focusing on the ideation phase of the design process. Today, the emphasis is still on clay modelling; however, also other modelling methods are added. Besides, we added moments of reflection in which the students have to record their results and think about the process they performed.

The course consists of the following parts:
- Modelling basic shape features
- Making multiple variants of an object in a short time
- Applying multiple modelling methods
- Reflecting on the learned methods

Table 1 gives an overview of the course parts. The individual parts will be discussed below. Of each part, it will be described what the students should learn, with which goal and how this will be performed in assignments for the students.

### 2.1. Modelling basic shape features

In this part of the course, students learn to model basic shape features in an expressive way (learning goal 4). It starts with a short lecture about the types and applications of clay. Lumps of different types of clay are available and the students can knead them and feel the difference in working with them. Pictures of applications are shown to the students. After this lecture, the students have to practice with plasticine. They have to make the following shape features:
- edges, sharp and rounded
- surfaces, flat and curved
assemblies of parts, with smooth, firm joints
bends, without cracks
carved details

This is illustrated in Figure 4. The house has sharp edges between the walls, but the roof top is rounded. The door and the windows are carved. The tree is assembled from parts. Its surfaces are curved, while the house contains flat surfaces. Finally, bending was applied for the tail of the cat.

2.2. Making multiple variants in a short time

In this part of the course, the students learn to use plasticine to model several ideas in a short time, as defined in the first learning goal. The students start with making multiple small models of boats, in half an hour. Another 30 minutes, variants of a 3D mouse have to be modelled. The 3D mouse should have three buttons and a track ball, and it should be able to use it in the air and on a desk top. To be able to compare, the students have to model the boat and the 3D mouse also in Rhino. Rhino is CAD software that is appropriate for conceptual design, because its focus is on easy modelling, not on exactness and correctness. The latter are important for a manufacturing model; however, they require extra attention of the designer, which, in the ideation phase, interferes with the idea generation. As a part of the minor, the students did already another Rhino assignment. So each student had sufficient experience to make the requested Rhino models.
2.3. Applying multiple modelling methods

Now learning goal 3 is practiced: Students have to apply different modelling methods. This part contains multiple assignments:

- making a sculpture of natural clay
- making a small model of a chair using different methods
- making a full scale chair of tubes and duct tape
- choosing multiple methods for modelling one object
- choosing a modelling method to prepare a model for a personal design

The main goal of the sculpture assignment is to let the students experience the differences in material and handling between the artificial plasticine and the natural, water based clay. The goal of this assignment is not to make rapidly many models. The students get more time for making the sculpture: one hour and a half. Compared to plasticine, natural clay is more fragile and breaks easily at places that are thin. So it is obvious that models of natural clay, in general, should be larger than those made of plasticine.

The next assignment was to use different modelling methods for the same type of object. The object for this assignment is a chair. Six chairs have to be made, each by applying a different method. The methods to be applied are: paper, foam, plasticine, natural clay, wire and Rhino. For each method, 15 minutes are available.

Then a full scale model of a chair is made. This assignment is done in teams. The teams use PVC tubes, which they connect with duct tape. Black plastic bags can be used to indicate the seat and the back of the chair. The teams get one hour to finish the chair. The goal of this assignment is not only to let the student apply another modelling method, but also to confront them with the effect of scale.

After that, the students have to model a chair for which they apply at least two different modelling methods. This chair will be further elaborated than the rapid models in the earlier assignments, so the students learn that they can, once a first choice is made, further detail the shape model. One hour is available for this assignment.

Finally, the students could apply one of the learned methods for their personal design project. The minor includes a project to make a personal design of a jewel. This project runs after the Rapid Modelling course. In the last hour of the course, students could generate and sketch ideas for their design and make small models, using materials as desired. For this, also Fimo [3] clay was available, in several colours. Fimo clay works like plasticine; however, it can be hardened by baking it a few minutes in an oven. Instead of working on this assignment, students can also work on the clay model they made in an earlier assignment. Now the clay model has dried and other operations can be applied, such as grinding. Some of the students may like to apply such operations to finish their clay model.

2.4. Reflecting on the learned methods

Questionnaires were used to let the students reflect on the use of the different methods. Besides, the questionnaires served another function: they tell if the students had already experience in the used methods, and how they appreciated the different methods. Three questionnaires were used. The first one is about the students’ opinions on the different methods they applied. The second one asks which methods they already used before the course, and which ones they expected to use in the future.

We also wanted to know if the course has effect on the students’ opinions about the use of the different modelling methods. To investigate that, the students were asked to fill a third questionnaire. After the Rapid Modelling course, the students did a project in which they had to make their personal design of a jewel. This project was the last part of the minor. At the end of the minor, the students were asked to fill the last questionnaire. This questionnaire mainly consisted of questions that were also asked earlier. By comparing the answers of the last questionnaire to the earlier ones, we could see if the students had changed in their application of modelling methods and their opinions about these methods. That tells something about the effect of the course.

In the first questionnaire, the students reflected on their use of different modelling methods. The questionnaire contained the following questions:

1. Are you satisfied with the model?
2. Does the model look like you had intended?
3. Do you think this method works pleasantly?
4. Do you think this method is difficult?
5. Was a quarter of an hour sufficient time?

All questions had to be answered for all practiced methods, viz. paper, foam, plasticine, natural clay, wire, Rhino and tubes. Answering had to be done by placing a check mark on a line that runs from “Not at
The second questionnaire was about previous and expected use of modelling methods. The questions of this inquiry are the following ones:
6. Before the minor, I used this method.
7. In the rest of the minor, I think I will use
8. After the minor, I think I will use

These questions were also answered by placing a check mark on a line. This time, the line runs from “Never” to “Often”. Besides lines for the methods that were used in the course, there were empty lines on which students could add possible other methods that they had used. An additional question asked the students to characterize each method in one word, or in a few words.

The last questionnaire mainly repeated earlier questions, to discover if the students changed in use of methods and their opinions about them. Also, one question asked their personal opinion on the effect of the course. Finally, they could add comments. Below are the questions of this final questionnaire:
9. Compared to before the Modelling Course, now I use method x less / more
10. Were you satisfied with the model?
11. Did the model look like you had intended?
12. Did you think this method works pleasantly?
13. Did you think this method is difficult?
14. Did you think this method is time-consuming?
15. In the future, I think I will use method x never / often
16. What has been the influence of the course on your designing?
17. Comments:

In addition to these questionnaires, the teachers were asked to indicate which methods they had seen the students applying.

The duration of the jewel project was restricted and every design project is different. Therefore, the data on the methods students applied during this project cannot be generalized. This data is not sufficient to predict what methods they will use in future projects. To compensate for this deficiency, we also asked what methods the students expected they were going to use in the future.

The results of all questions was analysed to see what the students’ opinions are about the different methods, and if those opinions had changed after the course. Further, it was investigated which methods were already used before the course (question 6), which methods were used after the course (questions 7 and 9), and which ones were expected to be used later (questions 8 and 15). The answers were compared to discover if, after the course, students used methods they did not use before.

The total data that was gathered consists of answers on 20 different questions about, in general, six different materials, by 40 different students. This makes 4800 answers. The real number may deviate from this, because not every subject answered each question and, at the other hand, some subjects added lines because they used methods that were not in the lists. Still, the number is too high to show every answer in the paper, and it is not necessary. Many answers vary much between individual students. Some students like a particular method, while others don’t, so in many cases the average answer of all students will be somewhere in the middle. In other words: the average will not be very negative or very positive. Such answers don’t tell us much. We are interested in the answers that are markedly positive or markedly negative, for a substantial part of the respondents. Those answers will be mentioned in the results section below. To quantify this, we divided the answers in three categories: low, neutral and high, as follows: An answer value is low if the check mark is in the left third part of the line and high if the check mark is in the right third part of the line, see Figure 6. The outcome of a question is mentioned positive if at least 50% of the responses are high. Similarly, the outcome of a question is mentioned negative if at least 50% of the responses are low. This applies to the questions that are answered by
more than two respondents. Outcomes that are based on only one or two respondents will be neglected.

3. RESULTS

This section will show the results of the different course assignments, in the same order as the previous section.

3.1. Modelling basic shape features

The students made the taught features as intended. A typical example is already shown above, in Figure 4. If this figure is compared to Figure 7, it is obvious that students differed in their representations of animals, trees and houses. Yet, the required shape elements could be found in their different models.

3.2. Making multiple variants in a short time

Figure 8 shows the variants of two students for the boat assignment. The lightest collared boats are of one student. He was able to make four boats. The other student did two boats (the darker ones). On average, students finished three models in 30 minutes. The results for the 3D mouse were similar. Apparently, the students were able to make small models in a short time.

3.3. Applying multiple modelling methods

Figure 9 shows some of the sculptures that were made of natural clay. The students made indeed larger object than with plasticine. Also, they prevented thin parts. Most of the sculptures showed no cracks after drying. As can be seen from the figure, the clay sculptures differ in appearance from the plasticine models.

Figure 1 showed already examples of the chair models that were made with the different tangible methods. In general, the students were well able to make the models within the time limit of 15 minutes. Sometimes, students made multiple models in that time. The reflections of the students on their models will be discussed in the next section. Also the next assignments were no problem. Figure 10 shows a full scale model of a chair, and a scale model made with multiple methods. A variety of models that were made for the jewel project can be seen in Figure 11.

3.4. Reflecting on the learned methods

First, we will discuss the results of the questionnaire about the methods that were applied for making chair models. The results will be organized per method. We will mention the opinions the majority of the students had in common. That means, as explained in the method section, that at least 50% of the students gave a markedly positive or negative response.

Paper worked pleasantly, it was not difficult, the time was sufficient and the model looked like it was intended. At the end of the minor, the subjects expressed again that working with paper is not
difficult, and the results are as intended. Plasticine and natural clay models also looked like intended and the available time was sufficient. Most subjects did not use these materials before the course and didn’t expect to use them after the minor. From natural clay they said it works pleasantly. Foam did not work pleasantly. The available time was sufficient. Wire was not used before by most of the students. Also, the majority did not expect to use it again. Tubes were not used before by the majority of the students, and they don’t expect they will use them in the future. They think it is not difficult and the available time was sufficient, however, it does not work pleasantly. Rhino worked pleasantly. The available time was sufficient. The subjects were content about the result and it looked like they had intended. All responding subjects tell they didn’t use Rhino before the course, but they will use it again, not only during the minor but also after it. At the end of the minor, they expressed these opinions again. SolidWorks (SW, [21]) was mentioned by seven subjects in the questionnaire that was answered during the course. They all had used it before the course, and most of them expected to use it during the minor and after. In the final questionnaire, four subjects mentioned SW. However, these four subjects were not the ones who had mentioned SW in the earlier questionnaire. Two of them thought it worked pleasantly, three of them expressed it was not very time consuming, the result was satisfactory and it looked like was intended. All of them expected to use SW again. Wood was used before the course by four subjects. They all expected to use it again during the minor. At the end of the minor, three subjects indicated they had used wood for the minor. They were all content about the result. Working with wood was not considered difficult or time consuming. Other materials were not reported by more than two subjects. There were quite a lot of different modelling methods that were applied. To mention some of them: MDF, beads, metal and plastic sheets, Catia [2], AutoCad [1], Grasshopper [9], fabric, welding, forging, rolling, cutting, lathing, casting, and laser cutting. After the Rapid Modelling course, the students had to make a personal design of a jewel. At the end of this assignment, the teachers were asked to indicate which modelling methods they had seen by the individual students. Rhino was used by all students. Eleven students used also other CAD software. Ten used SW, two Catia and two used Rhino add-ons such as Grasshopper. Metalworking was done by 16 subjects. This included welding, forging, rolling, cutting, lathing, bending of wire, and bending and cutting of sheet metal. Plastics were applied by 23 students, mainly foam (by 15 students) and plasticine (by 12 students). Other observed materials and methods were sheets, tubes, wires and thermoforming. Wood was used by nine students. Other observed materials were leather, silicones, natural clay,
concrete and Delft earth. Also laser cutting was applied.

When these observed methods are compared to the ones students indicated they had already used before the course, it appears that the students applied many methods that were not common for them. In total, 97 methods were observed by the teachers. From 53 of those, the students that applied them had indicated in the questionnaire that they did not use them before the course, or at least not often. The response of the teachers was about 36 students. From these students, 27 applied methods from which they had indicated in the questionnaire that they had not often used them before. Let us also look to the questions about this in the questionnaire, in particular the question: “What has been the influence of the course on your designing?” 24 students answered this question. Fourteen subjects wrote that the course did influence their approach. This is confirmed by the observations of the teachers. For twelve of these fourteen subjects, teachers mention the use of materials that the subjects did not use much before the course (as indicated by the students in their questionnaire). The materials that students started to apply after the course were plasticine by eight students, paper by three students foam by five students and Rhino by two students. From two of the fourteen students mentioned above, the teachers did not mention methods that they did not use before. However, those students report themselves that they started to use Rhino more often.

Five students answered that the course did not have much influence on their approach. Yet four of them mention in the questionnaire at least one method they applied more often than before the course. Also the teachers noted some methods they applied more often, for three of them.

The five remaining students who answered the question were positive about the course; however, their remarks did not make clear if the course had influenced their approach.

37 students answered the question “Compared to before the Modelling Course, now I use method x less/more often”. Out of them, 34 mentioned at least one method they used more often. 23 of them mention multiple methods. Rhino is mentioned most frequently: by 28 subjects. Foam was mentioned by 11 subjects and plasticine by 10.

Next, we compare the answers of the last questionnaire to the answers on the similar questions in the earlier questionnaires. Again, not all answers will be discussed one by one. From the last questionnaire, we mention those answers that were remarkably different from the answers on the same questions in the earlier questionnaires.

At the end of the minor, scores were higher for the students’ satisfaction about the models of natural clay, wire and Rhino. Modelling with foam was rated as less unpleasant than during the course, and also less difficult. The latter applies also for modelling with plasticine. Students were also more positive about the amount of time that was necessary to make the models. Furthermore, there were higher expectations about the future use of Rhino, paper and tubes. Figure 12 depicts the impact of the workshop per technique. The question whether they will use a particular technique in the future was compared to prior experience – Rhino (60%) and plasticine (52%) received the highest praise, while the others received a mixed result.

Lower scores appear for the students’ satisfaction about paper models. They stated less often that the paper models were as intended. The latter also applies for models of plasticine, natural clay and wire. Finally, modelling with paper and wire was rated as less pleasant than in the earlier questionnaire.

4. CONCLUSIONS

During idea generation, students tend to choose a concept too early, instead of exploring the full range

Figure 12 Impact of workshop per technique in percentages (n=40).
of possibilities. Partly, this is because students are not aware of all possibilities to make many models in a few minutes. Also, lack of modelling skills can be a threshold to make more models and explore more possibilities. We developed a course for rapid modelling in an evolutionary way. Initially, students learned to generate multiple small clay models in a short time. The last year, the course is extended with other modelling methods, such as modelling with foam, paper and wire. Questionnaires were filled by the students, during the modelling course, and later, after they finished a design project. Results from the questionnaires show that students indeed applied many different modelling methods for their latest design process. Many students applied methods they were not used to apply before.

Students were positive about paper, Rhino, SW, plasticine and natural clay. However, most students didn’t expect they will use plasticine or natural clay again. Also, wires and tubes are not expected to be used again. Most students think working with foam is not pleasant, but still many expect to use it again. Paper is assessed as quick and easy. Wood is not, but those who used it were content about the result.

We conclude from the above that, after the Rapid Modelling course, many students applied methods they did not frequently use before. Yet, not very many expect that they will use those methods very often again. A remarkable exception is Rhino. Students are very positive about this CAD modeller. They think working with it is fun, and they like the results. Considering this, it would have been beneficial if the students had learned to master Rhino earlier. Rhino is in particular appropriate for the conceptualization phase. At the faculty Industrial Design Engineering, bachelor students practice ideation and conceptualization already from the first weeks they start their study. However, Rhino is only taught as an elective in the Master. This is a pity, because it is very appropriate for the design tasks in the bachelors. Besides, every design student should be able to use a CAD modeller that is appropriate for ideation and conceptualization. Based on the results of this research, we think that Bachelor Design students should learn such a CAD modeller in the beginning of the bachelors’ programme.

In the course Rapid Modelling, students also worked with paper, foam, plasticine, natural clay and wire. However, the course was compressed in 12 hours. After the course, the students know the mentioned methods, and they have worked with them. The next step should be that they repeat using the learned methods. Then, after a while, they can apply them without thinking about it. Their attention can then be at the shapes they are developing, and they can have an open mind to see what is emerging, not only the intended, but also unintended effects [21]. Then there are good opportunities for new discoveries and new ideas. In this way, modelling will be more than externalizing intended shape; it will also be a discussion, reflection, and an evaluation at the same time [20]. Speaking about education, Schon [18] advocates having more emphasis on media as “a means of coming to see things in new ways”. In the course, several steps were important for the students. At first, they are now aware that the used methods exist and can easy and quickly be used. Secondly, they used the methods, so they also have some experience. The next step should be practicing, to make working with a particular method a routine. Verstijnen [26] has shown that it is easy to generate new ideas by combining existing ones. This can be done mentally, without support means. However, restructuring ideas into new ones is more difficult and requires supporting media and expertise. We think a course in the first year of the Bachelors would be very appropriate for that. Students can then learn several ideation methods and practice them. Next, they can apply the learned methods routinely in the many design assignments they will get in the Bachelor’s and later, in the Master’s. Because of their expertise, they will not have to think about the modelling methods and methods, but they can concentrate on the shape they are developing. Having expertise with some physical media will enable the students to get more ideas [23] and in an earlier stage, because physical modelling can easily be done before exact details and dimensions are determined. Besides, working with 3D media is a useful addition to sketching abilities, because working in 3D gives better feedback about spatial features and relationships that were not foreseen [15].

REFERENCES


[31] www.digitaltutors.com/
