

CASE Tools versus Pencil and Paper

A student's perspective on modeling software design

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Abstract. In this paper we study students' reflections on different ways of creating a model of a software design: either through using a CASE tool or via pencil and paper. In particular, we asked students how the different means of creating a design affected their learning of software design. Beyond the advantages and limitations of the two styles, our findings suggest that there is no strict line separating the two approaches. Both share a number of positive characteristics related to sketchy designs, collaboration, and exploration of design issues; and both could be improved with respect to portability and understandability.

1 Introduction

In this work, we study how students perceive the use of modeling tools in comparison to working with pencil and paper in their course assignments. Based on a literature study from 2009 [8] this is the first report from a course where two different technologies have been used to teach software architecture. The study consisted of a series of design tasks followed by an online survey designed to collect both quantitative and qualitative data about the students' perceptions of the two styles.

Our findings suggest that each of these styles comes with its own advantages and limitations. For example, tools are valued for clarity and changeability whereas working with pencil and paper is valued for when creating first ideas/mock-ups of the design. Both approaches have a number of positive characteristics related to sketchy designs, collaboration, and exploration of design issues; and both could be improved with respect to portability and understandability.

Our contribution is two-fold: First, the study gives a starting point for a deeper understanding of how students relate to design tools and how this impacts their learning and understanding of software architecture. Second, the survey helps to elicit requirements for modeling tools through the lens of students' experience [4].

The rest of the paper is structured as follows. In Section 2, we introduce our study design. In Section 3, we present the main results of the study organized

along a number of identified themes, together with related work. A summative discussion of the results is then given in Section 4. Finally, in Section 5, we draw some final conclusions and point out directions for future work.

2 Study Design

In order to conduct the study, second year software engineering students were chosen to complete six assignments in a team of 6-7 members as part of a course on software architecture. Each assignment consisted of making or modifying a structural design diagram for a system. Each team is supervised by one teaching assistant in addition to a course teacher. The course is part of a three year international bachelor's programme on Software Engineering and Management at the University of Gothenburg. The first three assignments were asked to be made with pencil and paper. The second set of three assignments was asked to be made with any CASE tool of choice. Example used tools included IBM Rational Rhapsody and Eclipse Papyrus.

A questionnaire was then designed to capture the perceptions of the students regarding the design tasks. The survey was created around four qualities representing both the programming-in-the-large as well as the communication aspects of software architecture [5]:

1. *Synthesis*: Creating a design for a given modeling problem.
2. *Modifiability*: Changing a design as part of the team work or based on the feedback from the supervisor.
3. *Efficiency*: Time efficiency when incorporating changes to an existing design and collaborating with other team members.
4. *Understandability*: Understanding the design by another team member as well as comprehending the domain model.

The questionnaire consisted of a first set of 11 closed-ended questions and a second set of 4 open-ended questions in order to acquire both breadth and depth of understanding. The first two questions of the first set were used to evaluate the knowledge of students of CASE tools and UML. The remaining 9 questions used a Likert scale from 0 to 10, where a value is given to mark student's tendency towards either CASE tools or pencil and paper. Figure 1 depicts an example question evaluating the modifiability quality of the modeling activities. The second set of questions was used to collect feedback related to the advantages and limitations of the two approaches.

In total, the survey questionnaire was answered by 44 students. The knowledge of CASE tools varied from 'none' to 'very experienced' with a bias towards 'some experience'. Only 3 students (7%) were unfamiliar with the tool(s). Furthermore, most students (90%) self-assessed that they had good knowledge of UML.



Fig. 1. Example Survey Question.

3 Results

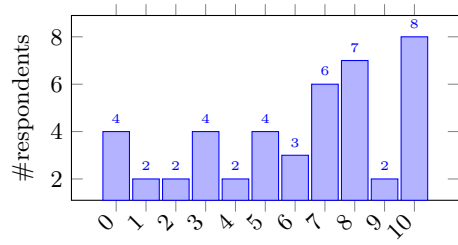
A sample of students' answers to the questions is presented in Figure 2. On the Likert scale used, a mark of 4 or lower indicates a tendency towards pencil and paper whereas a mark of 6 or greater indicates preference of CASE tools. Mark 5 is perceived as a neutral answer. Based on the answers and free form feedback, we identified a number of themes around which we formulated our conclusions and recommendations. The quotations referred in the subsequent sections are transcribed exactly as reported by the students.

3.1 Clarity/Simplicity

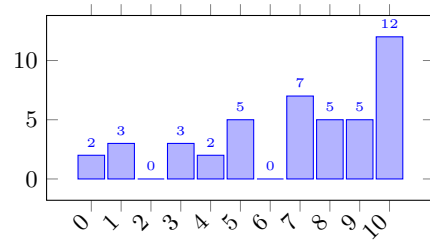
Evaluating the clarity aspect of students' designs in relation to using pencil and paper or a CASE tool was addressed by more than one survey question. This is in line with how researchers and practitioners have defined the term clarity in UML designs. For example, in [10], the authors associate clarity with the ability to represent real world domains uniquely using the available language constructs. In [9], the concept of clarity has been considered as a purely aesthetic aspect that is based on the graphical arrangement of the elements composing the model. A third perspective [3] has linked clarity to the ability to prescribe steps involved in the creation of a model, evolving the model, and the examination of it by different people with different skills. In this study, we consider understandability, changeability and collaboration as indicators of clarity.

When asked about the easiness "to understand someone else's hand-drawn model or a model drawn in a tool" (see Figure 2D), a majority of the students favored models created using a CASE tool (28 respondents - 64%). In contrast only 2 students (4%) preferred pencil and paper while 14 students (32%) had no clear preference. Tool superiority is confirmed when it comes to the ability to change a model (which is another clarity indicator, see Figure 2B) with 29 students (66%) in favor of tools against 10 respondents (23%) preferring design by hand approach and only 5 subjects (11%) with no clear preference. Furthermore, a third clarity indicator, collaboration, strengthened the position of tools over the pencil-and-paper approach (see Figure 2F): 20 students (45%) in support of tools against 13 respondents (30%) favoring design by hand while 11 respondents (25%) had no clear inclination.

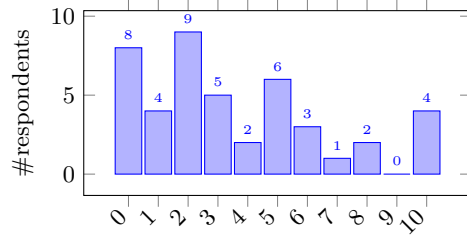
According to students' feedback, the clarity advantage of tools maybe further enhanced by adding support for interactive pen displays & digital drawing



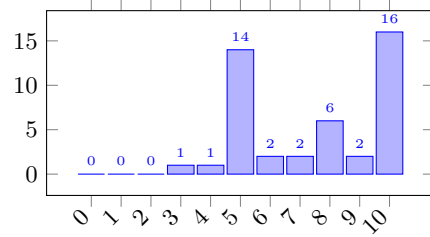
A. Was it easier to create a design by hand or using a tool?



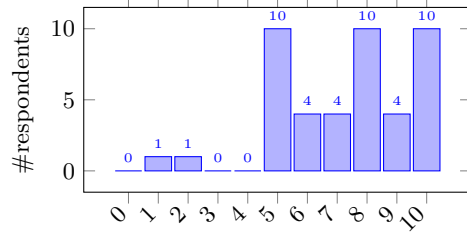
B. Was it easier to change a design by hand or using a tool?



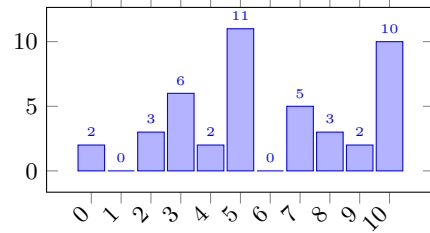
C. Was it more time consuming to change a design by hand or using a tool?



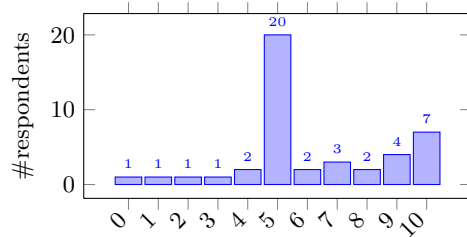
D. Was it easier to understand someone else's hand-drawn model or a model drawn in a tool?



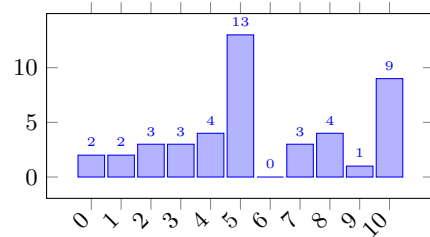
E. Which approach led to a better quality of your design?



F. Which approach was easier to collaborate on creating a design?



G. Which approach led to more useful feedback on the task from the supervisors?



H. Which approach helped you more in learning UML?

Fig. 2. A Sample of Students' Answers to the Questionnaire.

technologies, which “would mean that hand drawn shapes can be translated into UML elements”.

3.2 Easiness

In relation to the question “Was it easier to create a design by hand or using a tool” (see Figure 2A) a majority of the students, 26 out of 44 (59%), were in favor of using a CASE tool. In contrast, 14 students (32%) answered that they found pencil and paper easier. Four students were neutral (9%).

A barrier with the tools is that you need to learn them before you can get started designing “Sometimes the CASE tools can get pretty complicated and overwhelming to use, due to tons of functionality”. At the same time, one comment regarding pencil and paper was that you need to “Practice a little more drawing skill” for pencil and paper to become more useful since the clarity of the design partially depends on the designers drawing skills.

The possibility to get started with the design straight away is an aspect that has a positive impact on the ability to collaborate on a design - disregarding if using pencil and paper or a CASE tool. According to one student the problem of the tools is that “they all require you to read the documentation even to do quite trivial tasks. There are no shortage of functions but a lack of displaying how to use those functions to the user in an intuitive way” - this relates to Whittle et al. who claim that MDE tools seldom match people, instead people have to match the tools [11]. That pencil and paper was popular in contrast is not a surprise since “the main benefit of pencil and paper is that you can very quickly sketch a design”. But many students also remarked that one benefit of the tools is that “you can start right away without too much planning ahead and do designs and improve on designs overtime with the group, it creates more discussion.

Regarding the question “Was it easier to change a design by hand or using a tool?” (see Figure 2B) the students were again in favor of the tools. 29 students (66%) preferred the CASE tools while ten students (23%) preferred pencil and paper. Five students were neutral (11%).

Those in favor of the tools emphasized the ability to modify the design because it was “Easy to manipulate and change designs, also easy to make them readable” and that the tools were “Flexible, easy to use, editing the design, sketching the design, it was simple to use and share with the group members”. In contrast, one student remarked that “only after we got to the point that we thought we had fully understood the problem, did we [...] move on to using a CASE tool”.

3.3 Flexibility/Changeability

Creating a design is an evolutionary process: it involves trying out design decisions and continuous polishing (i.e. adjusting, refactoring) based on increasing insight. Therefore the ease of changing a design representation is an important aspect regarding the choice of technology. In the survey we asked “Was it easier to change a design by hand (pencil and paper) or using a tool?” (see Figure 2B)

The responses show a clear pattern that respondents believe that the case tool provides better support for changing of the design. 66% of the students favored a CASE tool for changing the model during the design activity.

There were a number of disadvantages of using pencil and paper related to flexibility and changeability mentioned; “Hand drawing can’t be upgraded.”, and “A paper might get torn when there are too many changes”. On the other hand it seems like some of the problems by using paper and pencil – such as “need of huge piece of paper” and “better erasers” – disappear when using whiteboards “Using a whiteboard makes it easier to adjust designs” and “A board makes it easier to erase content and change the design instead of risking it looking messy.”

The following advantages of CASE tools are mentioned by the students: The ease by which one can change and redo diagrams and the ease of automatic line drawing. On the other hand, some students indicted that it takes more time to draw with a CASE tool than with a whiteboard. This might be the case since students have to learn how to draw the diagram in a strict way following the rules of the tool.

It is interesting to see that both CASE tool and paper receive comments of being ‘too time-consuming’. It may be that there is a general feeling that creating a design is time-consuming, independent of the way it is created.

3.4 Learning

To explore how the students’ learning experiences were affected by the two different implementation strategies they were asked “Which approach (pencil and paper vs CASE tool) helped you more in learning UML?” (see Figure 2H), where UML was used as the architectural description language for the course. 14 students (32%) preferred pencil and paper, 17 students (39%) favored the tool options, and 13 students (29%) were neutral.

Those in favor of the tools highlighted that the tool “made all options viewable and available, which is a helpful reminder of the choices to make when creating a diagram”. Some students also found the documentation a help since “the tools often have good documentation/descriptions of everything available to use”. One drawback with the tools is that “any tool needs its own time to be explored and get the basic understanding of it. Which takes us back to the aspect of easiness since in some cases the need to understand the documentation has a negative impact on creating a design and not only on the user experience.

In relation to “Which approach (pencil and paper vs CASE tool) led to more useful feedback on the task from the supervisors?” (see Figure 2G) 6 students (14%) favored pencil and paper, 18 students (41%) preferred CASE tools while 20 students (45%) were neutral. There were no comments relating to the question.

3.5 Speed/Efficiency

A majority of students find it more time consuming to change a design by hand (see Figure 2C). 28 students (64%) thought it was simpler to make changes using

a tool. But, there were students which found it faster to do hand drawing when discussing things. That might be one of the reason why 10 students (23%) found it more time consuming to use a tool.

The tool used in the course had been used by students in a previous course, so they were familiar with it. This becomes clear from this student comments: “Easier and less time consuming, especially when we had previous knowledge and experience of working with the tool.” So, the students seem to find in general the tool easier to use edit and change.

We did not distinguish between using pencil and paper or using a black board. Some students find it easier to erase and edit the drawing. This might indicate that they were using a black or white board. One student wrote: “Ease of changing mistakes and having quick brainstorming sessions with what we could or could not do”. Some students did mention that they used whiteboard: “use a whiteboard or similar which makes it easier to adjust design, not pencil and paper.” This can indicate that some of the students which were happy with hand-drawing did use whiteboard instead of pencil and paper.

Also, one student pointed out that: “I guess it would be the fact that you can do it anywhere anytime without the need of a computer.” This is also in some way referring to efficiency, you can do some work anywhere as long as you have paper and pencil.

3.6 Collaboration

There were more students happy with using a tool in collaborating then pencil and paper (see Figure 2F). 46% of the students thought that the tool was the best to use, but only 30% thought pencil and paper was the best. On the other hand, there were a number of students which think it was equally good to use both methods.

One reason might be that the student found the diagram in the tool easier to read. One student wrote: “it is clear and easy to understand. It is good to understand someone’s architecture.” Another student wrote: “it was simple to use and share with the group members”. In general we cannot see from this answer whether the students collaborated together at the same time or at different times. However, when using a tool it might be that some students read diagram edited by other group members, something which is harder to do with pencil and paper. So the collaboration is done via the tool.

There were some students which indicated that using paper or whiteboard during brainstorming was good, but then it was a need to transfer it to a tool: “Have it used only during brainstorm sessions so that you move onto using / converting it to a tool”. “I can see it being much easier and better to use say white boards in places where you can share ideas and change ideas on the fly whereas in a tool it’s a little harder / takes more time”. Some students also thought it was faster to use hand-drawn diagram while discussing things. This might be due to the fact that they also think it was easier to erase and edit the drawings.

3.7 Quality

In responding to the question “Which approach led to a better quality of your design?” (see Figure 2E), most students (32 respondents - 73%) favored tools over pencil and paper (2 respondents - 4%). A total of 10 students (23%) reported no preference.

Defining the quality of software designs has been focused on properties such as modularity, complexity, and completeness [7]. While these properties are linked to the design, some more specific notions of quality exist that focus on the representation of the design in the UML notation. For example [6] defines quality as the level of absence of defects in a UML model. We can see these categories back in the responses of the students.

According to the students, the reasons for the preference of tools include “simplicity, correctness and the ability to view things in packages without having to re draw everything”. Many respondents have stressed the fact that “the drawing looks more organized and clean”, which “makes it easier to change and re-arrange things”. The tool also helps in another important quality aspect which is “Keeping track of proper UML notation.”

4 Discussion

4.1 Commonalities and Differences

From the analysis of the comments on what the students found best with the CASE tools and using pencil and paper a list of shared positives was deduced, where both technologies ...

- ... were suitable for sketches.
- ... enabled the students to quickly get started with their designs.
- ... facilitated discussion.
- ... facilitated collaboration.
- ... enabled the exploration of the design issues.

According to the students, collaboration is dependent on how easy it is to create and change a design. Easiness can be achieved independent of how the design is created – tools enable clean designs and short lead times from idea to initial design while pencil and paper are suitable for drafts and sketches.

In the case of tools the possibility to list all possible options in terms of legal syntax (e.g. different association types and design patterns) as well as extensive documentation is mentioned as having both a positive and a negative impact on the user experience. On the positive side the options and documentation show the possibilities together with their theoretical foundation. On the negative side the students report that having to read pages of text before you can even start using the tool is a barrier. The large number of features of the UML notation leads to a high complexity of the tools which has a negative impact on user experience. In this regard, it has been acknowledged that tool complexity may cause student distraction in modelling courses [1].

This leads us to the list of suggestions for improvement for the two techniques:

Alignment Align the tasks and the modeling technique. This is a general claim in industry regarding modelling tools [11].

Sharing Regarding the tools it was difficult to transfer designs between different tools and version control was not trivial while for pencil and paper the students wanted digital representations so that the designs could be e-mailed.

Training The tools come with a learning curve to understand the user interface and supported features while some students found that their handwriting and drawing skills needed to improve for the designs to be consumable.

Emphasis It is difficult to emphasize specific design elements when using the tools while different pens and rulers would make it easier to distinguish between the hand drawn elements. Arlow et al. made the same claim as early as 1999 [2]!

Finally, several students claimed that nothing needed to be improved. An interesting observation is that while some students wanted the tools to support freer forms a recurring wish for pencil and paper was that they should come with a syntax checker. From a student perspective there seems to be a need for technologies supporting a middle ground such as smart whiteboards that convert sketches into digital and formal drawings.

4.2 Threats to validity

A threat to the internal validity is how the three first assignments were done using pencil and paper while the three last assignments used CASE tools. This means that the students learning of software architecture increased from the first to the second treatment. An external threat is that the findings are based on students' perception of using pencil and paper versus CASE tools and it is not certain that our findings are relevant for professionals. However, the aim of our study is to increase our understanding of the students' attitudes towards the two treatments in order to better align our teaching with their perceptions and experiences. If our findings are relevant to other academic settings is a question for future work.

5 Conclusions

The field of software architecture has evolved significantly over the last years and so has tool support for developing and consuming architectural design models. Yet there is little empirical data and research studying the effectiveness of these CASE tools. In this paper we have surveyed students of a software architecture class on their experiences in using tools for modeling software designs.

An interesting finding of our study is that neither CASE tools nor pencil and paper has an absolute advantage. Depending on contextual factors such as size of the model and frequency of change in the design either approach was preferred. While using tools is sometimes considered problematic [11], our students favored them for a number of tasks.

For making designs with pencil and paper we recommend to also provide training for this, esp. on how to draw and how to collaborate. As future work, we plan to organize a follow-up study with a second data gathering to evaluate the quality of the models produced through the use of CASE tools versus pencil and paper. We will run a controlled experiment to investigate between the two approaches. Future tools should be explored that integrate the flexibility of notation of pencil and paper and the automated support of tools. For this, tables and smart whiteboards are promising directions to explore.

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