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Feature Creep in Design Students' Works: Why and How it Happens in Student Design Processes

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ABSTRACT Many recent studies have focused on feature creep in professional design. However, although feature creep has received relatively little attention in student design works, feature creep does occur in design class. This study aims to gain a deeper understanding of feature creep in the work of design students through interviews with students, professors and teaching assistants (TAs). We present the results of our interviews on feature creep in design education, including its causes, strategies to avoid problems it causes, and a method of teaching students how to avoid it. Our results also show the necessity of educational guidance for dealing with feature creep. Based on our results, we formulate design implications for guiding more effective education to avoid feature creep problems.

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Introduction

Adding and emphasizing features is a common way to quickly differentiate a product and increase market sales (Lee *et al*, 2006; Lentz and Bleizeffer, 2007; Nowlis and Simonson, 1996). In the design field, the term 'feature' generally refers to 'form and function' and 'is one of the characteristics of a product'. Recently, various technologies and resources have made a greater number of interesting interactions and functions possible, enabling designers and engineers to adjust more flexibly to the various impacts and consequences of technology in the design domain. Therefore, adding and emphasizing features has become more popular than in the past, and many products, such as software, now have excessive functionality. This phenomenon of adding features to or emphasizing the current features of a product is termed 'feature creep' (Norman, 1998).

As many researchers have noted, this phenomenon is motivated by the assumption that having a greater number of features makes a product more useful or marketable. Adding features can increase product capability and provides positive differentiation (Carpenter *et al*, 1994). However, the inclusion of a large number of features through feature creep is not always beneficial for everyone. Related to the negative aspects of feature creep, many researchers have indicated that a high number of features tends to increase product complexity, which can decrease usability (Nielsen, 1993) and negatively affect user experience; for example, feature creep can be seen as a waste of resources (Janlert and Stolterman, 2010; Lee *et al*, 2006; Nielsen, 1993; Obendorf, 2009). Though every feature is useful to someone, as the designers intended, the increased number of features creates additional problems.

Feature creep can also be found in design classes. A student's digital yoga mat system, shown in Figure 1, is as a typical example. The mat has a multitude of functions, such as teaching yoga, ensuring correct posture, and managing training schedules, all combined through a minimal form factor. Although the mat has many features, its actual usefulness is questionable. Indeed, our interest in feature creep began with the observation that this tendency is caused by the inclusion of unnecessary technical materials or functions. We recognized the need for an effective educational method to help design students rectify feature creep. However, although feature creep does affect students, the details of how feature creep happens in design classes remain an enigma. Although much research has focused on preventing feature creep in commercial products, it is difficult to directly apply these solutions to the work of design students because the context of a design class is different from that of a practical business environment. Thus, it is important to better

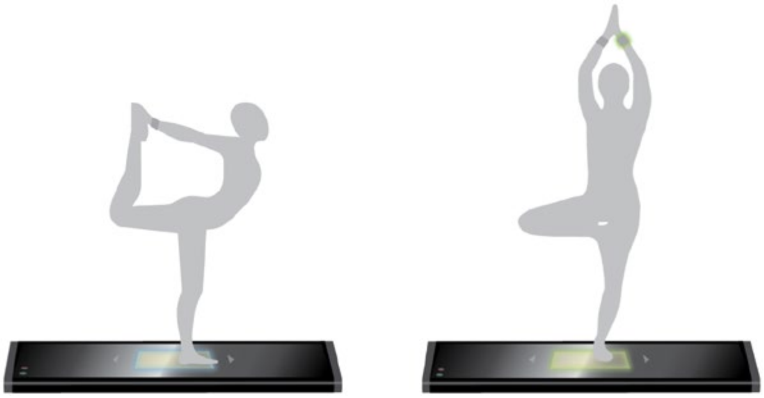

Figure 1 Digital yoga mat (student design).

understand feature creep in students' design work before developing an effective educational method for selecting user-appropriate features and resolving the problems faced by design students, who will eventually exert their influence on the design industry.

Our goal, then, is to provide insight into feature creep in design education, to explore why and how feature creep emerges in the classroom, and, by extension, to provide a foundation for developing educational methods for addressing issues related to feature creep. We chose the term 'feature creep' in this study to describe both the 'tendency' that occurs during the design process and the 'results' of adding and emphasizing features. To explore feature creep in students' design work, we conducted semi-structured interviews with design students, professors and teaching assistants (TAs) in an industrial design department. Specifically, this research contributes to a new understanding of how feature creep emerges during the student design process. Based on these results, we identify several practical implications for addressing feature creep in an educational context.

We caution that the perspective on feature creep adopted in this study does not assume that adding a large number of features to a product is a problem, although we present several ideas for preventing feature creep. Furthermore, this study does not adopt a conclusive stance advocating the minimization and simplification of features. The key point of this work is to explain how and why feature creep emerges from an educational standpoint.

Related Works

Studies on feature creep have focused on two aspects: how does a product affected by feature creep affect users and the market, and how can the problems caused by feature creep be overcome? According to previous researchers, adding features can increase product capability, and it provides positive differentiation by giving products clear advantages over those of competitors (Carpenter *et al*, 1994). Thus, adding features has become one of the most powerful ways to increase market sales in a short time (Lee *et al*, 2006; Lentz and Bleizeffer, 2007; Nowlis and Simonson, 1996). However, feature creep has negative aspects such as increasing complexity, affecting usability and the user experience negatively, wasting resources, and increasing costs (Janlert and Stolterman, 2010; Lee *et al*, 2006; Nielsen and Hackos, 1993; Obendorf, 2009).

The greatest problem associated with feature creep is the unnecessary increase in complexity (Janlert and Stolterman, 2010; Maeda, 2006; Obendorf, 2009; Thompson *et al*, 2005). Thus, much research on feature creep has tended to centre on complexity and the solutions for preventing problems by complexity. For example, McGrenere and Moore (2000) explored how users experience complex software and suggested specific guidance for interface design. Janlert and Stolterman (2010) explored the negative and positive aspects of complexity caused by additional features and suggested an analytical framework of complexity and strategies for dealing with complexity in Human Computer Interaction. Nowlis and Simonson (1996) investigated the factors that moderate the impact of a new feature on brand choice and suggested implications for predicting the sales. Rust *et al* (2006) suggested branding strategies for overcoming feature fatigue caused by complexity. These studies deal with feature creep mainly at the product planning level. Considering the real business context, it is true that significant numbers of features are carefully planned at the product planning level by marketers. However, features are decided not only during the planning phase but also during the designing phase in which product form, function and properties are developed by designers and engineers (Roozenburg and Eekels, 1995).

Recently, an attempt has been made to solve the complexity problem caused by feature creep in design classes at the designing level. Chang *et al* (2007) investigated a new approach based on simplicity that prevents feature creep in student designs. Their idea was to reduce complexity by limiting a device's number of input and output channels. This study suggested potential solutions for handling feature creep problems in the classroom. However, it lacked a deeper understanding of the processes by which feature creep emerges.

Many of the studies mentioned above have focused on simplicity to counteract feature creep. In design practice, the tendency exists to minimize and simplify features by hiding technical details or pursuing minimalism (Olsen and Malizia, 2012). This design tendency is also evident in the principles and philosophies of influential designers, such as 'Less is more' (Ludwig Mies van der Rohe) and 'Good design is as little design as possible' (Dieter Rams). Ostensibly, these principles appear to emphasize reducing only the number of features. However, the underlying meaning of these principles might be closer to 'Simplicity is about subtracting the obvious and adding the meaningful' (Maeda, 2006). Such principles can contribute to reducing useless features and the problems previously noted. However, excessively and unconditionally simplifying designs without considering a balance of design factors can also cause problems, such as poor usability and a decrease in the quality of the user experience (Norman, 2011; Olsen and Malizia, 2012). Therefore, it is necessary that design students consider the underlying meaning of simplicity carefully, that is, thoughtful reduction; however, relatively little attention was paid to an effective structural and educational method to deliver the core message of simplicity.

Previous studies on feature creep have focused more on the problem resulting from feature creep and suggesting solutions to the problem rather than focusing on the feature creep phenomenon itself. This study differs in that it aims to understand why and how feature creep emerges during the design process and then attempts to derive guidance on handling feature creep for teachers and students. This work also differs in that it studies feature creep at the design level within the purview of design education.

Method: Semi-structured Interview

For this study, we chose to use semi-structured interviews, which are particularly suitable for exploring experience and capturing the participant's point of view (Seidman, 2006).

Participants

We contacted three groups engaged in design education and recruited a total of 34 participants: 16 students, 14 TAs and four professors from an industrial design department.

We purposefully recruited students who had already taken most of the design courses of the industrial design curriculum to allow us to understand feature creep in design education from students who 'knew what they were doing' and 'can explain their experience from a learner's perspective' rather than novices. All of the TAs had worked in an industrial design department. All of the professors taught subjects related to interaction and product design. Detailed information about the participants is presented in Appendices 1 through 3.

Interview procedure

Before the interview, all participants were given detailed explanations of the concept of feature creep. We encouraged the student participants to bring any items to the interview that might help them recall their experiences related to feature creep. Two students brought their portfolios, one student brought a project report, eight students

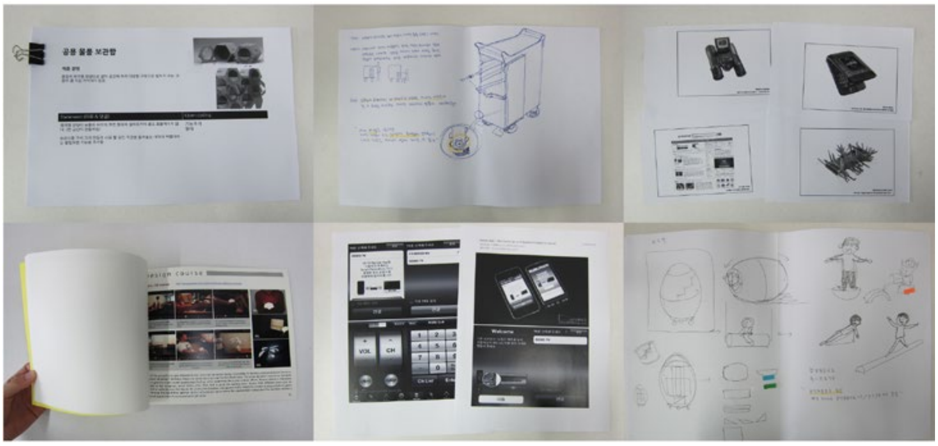

Figure 2 Items that students have brought to the interviews: portfolios, sketches and scrapbooks.

brought their sketches, and three students brought their example scraps (Figure 2).

The participants were asked to describe their experiences with feature creep in design classes, discuss design work affected by feature creep, and share their general thoughts about feature creep in the design classroom. More specifically, questions included what caused feature creep in the students' works, what challenges or successes the students faced, how the students handled feature creep, and how instructors teach the students how to manage feature creep. Each face-to-face interview lasted for approximately one hour. The student participants used the items they brought with them to supplement their explanations.

Data collection and analysis

All interviews were recorded and transcribed verbatim. Using a grounded theory coding process (Charmaz, 2006), we attempted to identify interesting and relevant topics. Hence, in open coding (which refers to the process of generating initial concepts from data by creating simple descriptive labels for useful statements), the key points are marked sentence by sentence with a series of codes extracted from the direct speech transcription. Using axial coding (which refers to the process of relating codes to each other), the codes were subsequently clustered and inferred into 12 categories. Finally, we divided the results into those pertaining to the causes of feature creep and those concerning strategies (of learning and teaching) for handling issues caused by feature creep in the classroom. This process of coding is shown briefly in the example given in Table 1.

Table 1 Example of open coding and axial coding

Transcript	*Open coding*	*Axial coding*
TA7: Some students wanted to show all they can do by adding more and more functions.	Expressing the passion	Wanting to make a difference
S6: umm … at that time, I felt my concept was weak. So I put more features because I believed it was one easy way to make my concept better.	Improving design easily	

Results: The Causes of Feature Creep Tendency In Design Class

The belief that 'more is better'

Feature creep in industry can be driven by a belief that 'more is better' (Lentz and Bleizeffer, 2007; Rust *et al*, 2006). Our results revealed that feature creep in student design is also caused by this belief. Students regard adding features as a way of increasing the attractiveness of a product. One interesting point is that students deal with features as a form factor for product aesthetics.

> When I was a sophomore, I believed more features would make it beautiful. (S13)
>
> Some students believe that more decoration means a higher degree of design completion. (P3)

We found that this belief is closely connected with the excessive passion of students. Most design students are full of passion for what they learn and desire to display the skills they have learned. From this desire, students add functionalities and emphasize them in their designs.

Interestingly, once students lose confidence and interest in their concept, they tend to add features to their design using a 'quantity over quality strategy' based on the belief that 'more is better' and that quantity will quickly improve their design.

Unclear purpose of design

Design students often lose sight of what they have actually designed. Participants described an unclear purpose of design as one driver of feature creep, as a clear design purpose is a good standard for generating and evaluating ideas.

We found three causes that can make it difficult for students to set and keep a design goal during the design process. The first cause is insufficient research into real user needs. According to the respondents, when students overlooked user research or did not conduct it properly in the beginning, they tended to struggle with setting a design goal. For example, students often made plans based on the assumption that they themselves were the end-users, or they recruited individuals who did not represent real users for the user study. The weakness of this recruitment method is that the results of user research can be easily biased, making it harder to ascertain real user needs.

> I recruited my friend (who was not an exact target user) sitting next to me, because it was an easy and quick way of recruiting. (S6)

Moreover, some challenges of conducting user research in the classroom were also reported, despite its advantages.

> The user-centred design [UCD] approach makes feature creep fade. But it's not always easy to perform the UCD method because it often requires considerable effort. (S2)

The next reason why students easily falter during the design process is conflict between their desire for self-expression and user needs. According to our interview, when there is a gap between the desire for self-expression and user needs, some students have difficulty keeping consistent goals throughout the design process, even if user understanding is clearly gained.

> There was a big gap between what I really wanted and what I have to do for users. I found myself forgetting user needs and adding features that are unimportant for users. (S7)

Finally, participants mentioned that feature creep occasionally stems from confusion between the aim of the class and the purpose of the product. For example, in some classes, the goal is to implement every possible functional feature to develop students' skills. In such cases, regardless of the purpose of the product, designing and implementing as many functions as possible can be a good strategy to improve one's skill. However, students may misunderstand and believe that this design strategy is essential to design.

Overlooking the evaluation of features

Student participants stated that the evaluation phase is crucial in reducing extravagant claims and unwarranted features and that feature creep can result from neglecting the evaluation of features. Participants reported several reasons for disregarding feature evaluation during the student design process, as outlined below. Consequently, they tend to add needless and irrelevant features.

The design students spent much more time on the ideation process of their design concept rather than evaluating the features.

> I spent more time on the ideation than on the decision-making because I thought that creative ideas primarily come from the ideation phase. And, at the end of the class, I had to skip a deeper reconsideration of the feature due to the time limit. (S12)

The lack of a method for evaluating the initial idea is noted as one of the difficulties of evaluation.

> In the conceptual design phase, there are relatively fewer evaluation methods for filtering an initial idea that is quite abstract. (TA2)

Easy Modification of Ongoing Design Works

During our interviews, it became apparent that feature creep among student designers is influenced by how easily they modify their ongoing works and how easily they access and utilize design resources or tools. During the process of software-based design, students have a much greater tendency to add features compared with when they design a tangible product because it is easier to modify software design components than the product design.

> When I designed a mobile application, I continually modified the features, adding sub-functions until the end of the work. I think that the easily editable process encouraged me to add more and more features. (S14)

Misunderstanding of Feedback or Instructions from Teachers and Colleagues

Feedback or the preferences of teachers also influence design students, which can lead to feature creep. If a professor prefers many features, students will alter their designs to reflect their professors' opinions to obtain good grades.

> In a software interface design class, the professor wanted the students to implement as many features as possible regardless of necessity, so I had to design all the menus on one screen even though I didn't want to do. (S8)

Misunderstanding the language of teachers and colleagues can also indirectly lead to feature creep.

> The professor just said to me, 'Um, this is just problematic … come on…'. I was so confused. (S15)

> I tried to tell students why the features could be needless for users, but the students didn't understand my words well. (TA14)

Less Strict Restrictions Than When Designing in the Professional Field

According to our interviews, feature creep in design class centres on the fact that design students have less strict restrictions (such as a budget) on designing than do professional designers. Therefore, students can include features without the burdens of cost or technology for realizing them.

> One team suggested the concept of a wastebasket with the function of a pinball game. That pinball game function came from the goal of their design: 'to encourage garbage collection by making the behaviour of throwing out garbage fun'. The goal was quite reasonable, but they didn't care about the cost and the mechanism needed to implement it. (TA14)

An underlying concern about restrictions in classroom was also reported.

> As a teacher, it's not easy to set the level of restrictions (that are given to students in class) because I'm concerned that strict restrictions might hamper the idea generation. Design students are often fixated on the restrictions. (P3)

Although design problems and constraints in design education are not always unrealistic or abstract and many design classes deal with realistic problems in various ways, the educational context, by its nature, is less realistic than the industrial environment; thus, participants responded that this type of feature creep might emerge in design education.

Results: The Ways of Managing Feature Creep in Design Class

Strategies for managing feature creep by design students

From the interviews, we found three main ways for managing feature creep by students. First, the most common strategy design students use is to base their design process on their own and other's experiences related to feature creep in their ongoing work. Design students compared their design concepts with other design examples, both good and poor. For instance, the students referenced products that were successful in the market. Moreover, they evaluated their ongoing work based on their previous work. By comparing their work with others, they attempted to avoid repeating the same mistakes.

The second strategy is sharing opinions about design concepts between colleagues or teachers to use when looking for feature creep problems. By exchanging opinions, the participants find problems in their design concept and naturally compensate for the defects of feature creep. This strategy helps them broaden their horizons. Design students attempt to gain feedback because they do not often recognize problems by themselves.

> Frankly, I didn't know in the middle of my design process that my design was an example of feature creep. Getting comments from other people helped me find the problems of feature creep. (S2)

The third way is rethinking the design process, when they were faced with feature creep issues. During this act of rethinking, some participants explained that they continually asked themselves questions such as, 'What is the purpose of my design?' This helped them think about the product's purpose and the target users. Based on this rethinking process, the students were able to set standards with which to select appropriate functions for the product purpose.

> I ask myself 'why this feature?' repeatedly. If I can't answer this question, I discard the feature. (S12)

Students generally applied these strategies in the later stages of the design process because that is when they often detected feature creep.

> When I found myself adding useless features to my design, it was already too late to change my design. (S9)

Methods of teaching students to manage feature creep

From the interviews, we found that instructors use common design teaching skills rather than special skills focused on feature creep. To deliver related knowledge to students, teachers use critique, group discussion and some existing design methods.

The most common method of teaching how to manage feature creep issues in design studio classes is critique, which is the most comprehensive way to deliver design knowledge. In the critique process, professors emphasize a 'backup rationale' and to 'remember the purpose of design' to rethink the necessity of the feature.

> In the critique session, I asked students to write down the rationale for each feature briefly in one or two sentences. This method is more effective than we may think. (TA2)

Specifically, to remind students of the purpose of design, teachers often encourage their students to identify user needs and preferences.

> One student was designing a device for patients waiting for treatment in the hospital. Her design was full of many useless features. I suggested that she 'go to the hospital and ask patients how they like it.' (P3)

Participants also mentioned some difficulties with the critique process. First, it is not easy to teach what is wrong because design knowledge is implicit. Second, some students are so sensitive to direct feedback from their instructors that they tend to just follow the feedback without rethinking the design.

Participants responded that group discussion in class is also a useful way of teaching how to select features to implement because it helps students look at their ideas from various angles and to reflect a diversity of opinions in their decision-making. By exchanging opinions with others, students can improve their decision-making ability, including managing feature creep problems gradually.

Apart from critique and group discussion, professors and TAs were helped by design methods such as the use of scenarios and role playing to teach how to reduce the problems caused by feature creep and select appropriate features. These methods help the students grasp the needs of users and suggest standards for decision-making.

> I usually encourage students to make a scenario. By making the user scenario scene by scene, students can realize what features are needed or not. (P4)

Participants mentioned that applying design methods can elicit design requirements rigorously. However, participants reported that design methods require considerable time and effort, and sometimes it is difficult for students to reliably reflect on the results of the decision-making step while they are heavily occupied with carrying out user research.

Discussion and Guidance to Address Feature Creep in Design Class

In this section, we interpret the interview results and discuss their practical implications.

By reviewing the implications of our study, we were able to identify two unexpected responses from our interviewees. First, professors who participated in this study responded that experiencing feature creep can allow students to learn and develop the ability to select features for a design, regardless of the negative aspects of feature creep. We think that this response is closely connected to one of the main characteristics of design education: 'learning by doing' (Lawson, 2004). However, as our participants stated, it is necessary to consider feature creep from an educational viewpoint, and there is still room for discussion on how to improve the efficiency of learning methods and teaching students how to select appropriate features. As our results showed, teachers provide instruction to learners in an interactive situation in which knowledge is frequently implicit, and students remain confused about how to handle the feature creep problem during the learning process and may attempt to solve the problem by relying on intuition.

The second unexpected issue raised in our study is that students' strategies for managing feature creep are not directly connected with the causes of feature creep. For instance, although weak user understanding was noted as a main driver for feature creep, student respondents rarely mentioned that they have used user understanding activities to solve feature creep problems. Despite understanding users' obvious role in generating and evaluating features, why did the students not take advantage of it? This issue implies that there could be some challenges to adopting solutions for handling feature creep in students' real-life situations. To develop methods for handling feature creep, we think that it is necessary to look at the challenges that students face in handling feature creep problems.

Therefore, based on the educational challenges involved in general design, real classroom situations, and our interpretations of the findings of this study, we will now discuss some practical implications regarding effective ways to reduce the problems caused by feature creep in design classes.

Make the design process more flexible for students

Our results show that student participants tend to utilize solutions that can be easily and immediately conducted when problems present themselves rather than acting actively and directly to control feature creep (e.g. through user research). Our interpretation is closely related to the following two points: (1) most project-based design classes follow a sequential process; and (2) students generally detect feature creep in the later stages of the design process. Generally, most project-based classes follow a sequential design flow. This sequential design method moves in a linear fashion by beginning with user research and sequentially moving forward to design, implementation and additional steps until designers have a finished design. Basically, in this design process, there are some weaknesses, namely that a designer would not look backwards or forwards from his or her current step to fix possible problems. Therefore, if something goes wrong, the design usually must be heavily altered. In this process, because students are aware of their tendency towards feature creep in the late phase of the process, they do not have enough time to fix their design.

Moreover, in the design class, a certain period of time is generally allocated for each step of the sequential process (e.g. two weeks for user research, two weeks for concept design). The fixed duration of each step implies the possibility of severing the link between each step of design process and consequently acting as a hurdle for the iteration of each step. Indeed, our results also show that due to the schedule for each phase of design, students are reluctant to go backwards in the process.

Considering these issues, we suggest making the design process more flexible. For example, shortening the period for each step would possibly encourage the iteration of each step. Likewise, adopting other developmental processes, at least partially (e.g. the agile design process), could be one solution. The main advantage of these processes is that they make the design process flexible enough to adapt quickly and easily to changing requirements and trends (Cohn and Ford, 2003). These advantages have stimulated increasing interest in applying agile approaches in the product design domain. The other way of making design activity flexible is to increase the informal critique session. By shortening intervals in which the progress of the design is checked, the chances of finding problems and fixing them would increase.

Enhance UCD practice in a realistic way

Our results showed that weak UCD practices are a main driver of feature creep, and there are some challenges to conducting UCD with students.

Therefore, to resolve this issue, we recommend that teachers think about how to suggest more feasible solutions that suit the students' real situation rather than just pushing students into UCD. As previous studies have noted, the use of design methods in real design processes is not always the same in practice as in theory (Günther and Ehrlenspiel, 1999), and thus it is important to understand the relationship between the use of tools and designers. Therefore, it would be helpful to ascertain the causes of feature creep that students are faced with and the stages at which they most often encounter these problems. For example, it is possible to provide comments relative to the student's step in the process. If feature creep is detected in the early design phases, then conducting more user research (e.g. interviews) would be helpful for students. If feature creep is discovered in the late phase of the design process, then reminding students of user needs or conducting a simple user test is more valid than completely re-conducting user research. The other way is to help students search for appropriate UCD methods easily. Using IDEO method cards (Stout, 2003) is one method. Through enhanced UCD practice, students can elicit robust design requirements, which can be used as criteria for generating and evaluating the appropriateness of certain features.

Help design students remember what the features are designed for

A clear design goal is important to making appropriate choices and generating new and more relevant design alternatives (Keeney, 2004). However, our results showed that design students often lose sight of the purpose of their design and the identity of the target user, often in the middle of the design process, even if the design goal is set properly. Losing focus on the design purpose is characteristically associated with a design problem that is ill-defined and ill-structured (Cross, 2007). Thus, a design novice easily becomes bogged down in attempts to understand the design problem and can easily alter and forget the design purpose during the design process (Cross, 2007). This causes design students to add undue features when they conceive of features in their design.

One implication is to check the purpose of each phase of the design process and then continually restate that purpose during every step of the design process. This strategy is reminiscent of 'not seeing the forest for the trees'. For instance, posting a simple catchphrase representing the design goal or a visual about the target user and the usage context on the wall of the design working room would be helpful, allowing students to keep the purpose of the product in mind. In cases like this, feedback about progress toward goals can have a positive effect on self-efficacy and achievement. Such reminders of design goals could be helpful in the selection and generation of appropriate features to serve the design purpose.

Support for the rapid and simple evaluation of features

Our results show that the feature creep tendency emerges when the design is not evaluated properly. Firstly, unclear evaluation criteria can be caused by a weak understanding of the intended user. In this case, gaining clear understanding of the user and the design requirements is required. Secondly, students sometimes fail to use appropriate evaluation methods. According to the interviews, even if a clear understanding of the user is gained, design students have a difficult time evaluating their design for several reasons, including a lack of knowledge about the methods involved and difficulties in evaluating an initial conceptual idea using analytical evaluation methods. This observation is consistent with previous studies on the use of design methods which suggest that designers rarely follow the theoretical methodology prescribed in their daily work (Günther and Ehrlenspiel, 1999). Consequently, the lack of evaluation demonstrated in our results naturally reduces the iteration of the design process, although selection and evaluation are iterative processes that must be embedded in the development of new products for good design (Rodgers and Milton, 2011).

One implication of this finding is that evaluation through self-questioning would allow students to quickly and easily articulate a feature's appropriateness or inappropriateness. It is possible to use a series of questions to engage the student in a reflective dialogue about how and why each feature was added. For example, such questions may prompt students to evaluate the necessity, redundancy, and harmony of each feature within a social context. Furthermore, to avoid feature creep caused by technical resources, the efficiency and feasibility of the product in the given context can be tested. This evaluation via self-questioning would be more useful for evaluating the initial or abstract idea. Quick and easy evaluation would enhance self-reflection on the ongoing design and learning processes. It may also be helpful to boost iteration of the design process, which contributes to improved design results.

Let students consider various constraints

We determined that placing restrictions on design problems play a role in filtering unfeasible ideas. However, it is relatively difficult for students to consider the constraints compared with those prevailing in the industry. Moreover, there is a concern that students easily become fixated on restrictions because design novices often pursue a 'depth-first' approach to a problem and get stuck with small details (Cross, 2007). Therefore design teachers must consider ways of searching for creative solutions within the set design constraints dictated by the curriculum.

There are two possible ways to consider design constraints during the design process. One is to let students learn about the constraints themselves by analysing the design problem and identifying the context of usage. By doing this, students clarify the obstacles and constraints of their design project. Referring to existing design approaches, such as the Vision in Product design (ViP) approach (Hekkert and van Dijk, 2011), which is a context-driven design method, can help clarify more specific restrictions indirectly through in-depth observation of the context.

The second way is to give students restrictions (such as a budget) or require that they implement the projects in a way that might result in a more careful selection of the features they want to implement.

Applying the core concept of the Design for X (Huang, 1996) approach in a design class could be one way to practice designing under specific restrictions. To give students more realistic problems through cooperation with an industry project can also be one way to deal with various constraints. This need to consider real-world limitations can offer students learning experiences that correspond to the responsibilities of professional design practice (Fraher and Martinson, 2011) as well as provide an opportunity to reconsider more precisely the value of features from the perspective of real users.

Help students better understand the teachers' comments on feature creep

Our results show that it is useful to exchange comments when seeking to uncover feature creep problems. However, the results of our study also show that design students may not fully understand the intention behind instructor's comments on their feature creep tendencies.

Therefore, one implication is that teachers provide convincing and explicit explanations about their comments on students' feature creep while leaving them room to think for themselves. For instance, before commenting, it is a good idea to ask an open-ended question like 'what if this feature is removed?' According to previous studies, comments that included explicit and descriptive explanations and reasons tend to be well understood by students and enhance the process of learning design (Rodgers and Milton, 2011; Taylor, 2011; van Dooren *et al*, 2014). At the same time, it is also important not to interfere with students' ability to think deeply, not only because it is crucial for students to understand the instructor's comments but also because it is important to help them achieve understanding by thinking through problems themselves rather than being explicitly directed towards a given solution (Taylor, 2011). Teachers also need to remain aware of the pitfalls of giving direct and strict comments, because some students unquestioningly follow the directions given by their professors. Teachers' awareness of explicit and convincing comments might be helpful to improve students' understanding of the comments on the feature creep issue.

Conclusion

Feature creep is a complex topic because it is connected to many issues and various points of view. This study has attempted to gain a deeper understanding of why and how feature creep occurs during the student design process by examining the causes of feature creep, strategies to manage it, and teaching skills that can help students avoid problems caused by feature creep. Finally, we discussed a number of suggestions to manage feature creep in the classroom. The argument here is that when features are added, we should engage in a critical, reflective dialogue about how and why these features are selected. By enhancing the understanding of feature creep in students' design work, we hope this study will provide a background that will allow us to develop a design method that can prevent excessive feature creep in design students' work. We also expect that the results of this study will contribute to design students by giving them an opportunity to develop their design ability in such a way as to find solutions to the feature creep problem. To enhance the results and implications of this work, further studies may include an observational study for understanding the activities of student designers that are related to feature creep tendency. Moreover, to develop more specific and direct solutions for handling feature creep, a further direction for research could be to develop a new design method for design education that reflects the results and implications of this study and by utilizing further studies on design education and design methods.

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Appendix 1 Participants: students

Participant index	*Educational background*
S1~S14	Senior students majoring in industrial design
S15, S16	Master's students majoring in industrial design

Appendix 2 Participants: TAs

Participant index	*Teaching experience (semester)*	*Educational background*
TA1	2	Bachelor's degree in visual design and computer science Master's degree in digital media design
TA2	6	Bachelor's degree in architecture Master's degree in communication design
TA3	2	Bachelor's degree in industrial engineering
TA4	1	Bachelor's degree in industrial design
TA5	2	
TA6	1	
TA7	1	
TA8	1	
TA9	2	Bachelor's and Master's degree in industrial design
TA10	6	
TA11	2	
TA12	4	
TA13	5	
TA14	2	

Appendix 3 Participants: professors

Participant index	*Educational background*	*Teaching experience (year)*	*Industrial work experience (year)*
P1	Industrial design	8	2
P2		10	9
P3		10	None
P4		4	10

Biography

Boram Lee received her PhD at KAIST in 2015. She is currently a senior designer at Samsung Electronics. She is interested in design methods, interaction design and user experience. She has participated in design research and design projects for corporations and organizations in South Korea, including Samsung and LG.

Woohun Lee is a professor in the Department of Industrial Design at KAIST, where he leads the Design Media Laboratory. His lab investigates alternative ways of communication between humans and artifacts and develops new design media, interactive media, and entertainment media. He has exhibited his works at SIGGRAPH Emerging Technologies six times since 2007. He was also awarded the Grand Prix du Jury at Laval Virtual 2012.

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