Title:
Improving the Learning Experience within MCAD Education: The Provision of Feedback on CAD Model Quality and Dormant Deficiency in Real-Time

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Introduction:
The potential of feedback for improving performance and enhancing learning outcomes is widely acknowledged in most fields and disciplines. In particular, feedback within formative assessment is considered by many experts to be a crucial element of appraisal and evaluation in the learning process. However, due to the complexity of learning processes and several variables that moderate the effectiveness of feedback and its means of implementation, understanding the workings of, and deriving generalizations based on empirical evidence from, this powerful educational intervention still poses a challenge. This is even more so if one takes into account the recent trend of progressively expanding the use of computer-based learning environments and blended course learning. In such cases, feedback provision is increasingly autonomous and it is invoked as well as driven by the interaction of students with a computerized learning environment. During the restructuring of a CAD course for mechanical engineering (MCAD), after a promising pilot run, an interactive feedback intervention was introduced, together with other educational measures, through a computer-based agent in the form of a software tool (cf. [10]). To obtain a better insight into the effect of this feedback intervention and how it was received, rated, and actually used by students, a two-part study was conducted analyzing empirical data relating to the viewpoints of the teacher and of students. In this paper results and findings pertaining to the first part of this study are presented and discussed.

Within the context of MCAD education, one of the recent trends outlined above is feedback intervention based on computerized approaches such as software tool agents oriented toward the automation of CAD model grading. However, as these computerized approaches are still in their infancy, the type and complexity of CAD models that can be analyzed, and the quality of the feedback that is generated, are still quite limited. Moreover, the concept that students should be allowed to use the same software tools as those which teachers use to grade CAD models produces further difficulties. Not only is there a limited feedback structure, but also, from the methodological and conceptual approach, grading, as traditionally practiced within the educational context, provides feedback that is based on a finalized result, and thus always contains one assessment criterion that is related to the completeness of a solution. Being structured in this manner, it cannot be a direct part of the process and learning experience during the performance itself, that is the design, creation, and alteration of a CAD model. Examples of recent approaches for technical drawings and 2D CAD files can be found in [2,7]. Results and examples of recent approaches for 3D CAD models and related empirical studies are reported in [1,6,9]. An interesting approach to providing visual feedback for automated CAD model grading using heat maps is reported in [8]. Further discussions on the subject of automated CAD model grading, including a summary of the literature and pointers to gaps in research, can be found in [4].

Research Questions and Method:

The basic goal and purpose of any learning experience are seated in acquiring the skills, knowledge, and competency to change and improve an existing behavior or to create a new one. Those changes in behavior should have measurable impacts that relate to key metrics indicating success in achieving the desired learning outcome. Here feedback intervention is one of the most powerful educational interventions, though there is remarkable variability in its effects. The objective of the first part of this two-part study was to determine and better understand the effects of the newly introduced feedback intervention on student learning and performance from the teacher perspective. In particular, the study presented in this paper addressed the following research questions:

RQ1: To what degree does feedback intervention in the form of a student software tool impact the learning experience as well as the outcome, and what are the feedback effects on student achievement in the context of creating robust and best practice compliant parametric feature-based CAD models?

RQ2: To what extent do the effects and characteristics of feedback pertain to goals related to CAD model creation, task complexity, and student performance challenges?

The study was conducted through a quasi-experimental research design with two sets (control / experimental) of student-created CAD models. The control set consisted of CAD models that had been submitted by students before the feedback intervention was introduced. The experimental set consisted of CAD models that were submitted by students after introduction of the feedback intervention. All CAD models used in the study were created as part of concrete exercise assignments and CAD laboratory activities, which are components of an actual CAD course for mechanical engineering at the institution where the authors operate. After initial model validity and data integrity checks, and a statistical power analysis, a total of N = 166 (control n = 74 / experimental n = 92) student-created CAD models were deployed in the study. All CAD models that were deployed in the study were individually analyzed and assessed by the authors. Results obtained were then cross-checked to verify the accuracy, correctness, and integrity of the analysis and its outcome.

Analysis, Results, and Discussion:

Analysis and assessment of the feature-based CAD models created by students throughout a series of design and modeling exercises revealed a considerable improvement in the quality of those CAD models created by students who had been provided with an improved learning experience using software tool based interactive feedback. Under this feedback intervention, the proportion of CAD models that contained features with warning / failure status was reduced from 13.51% to 5.43%. The proportion of CAD models that contained un-renamed features was reduced from 78.38% to 57.61%. However, the greatest improvement found during the analysis was in the proportion of CAD models that contained under-constrained features. Here the proportion was reduced from 21.62% to 5.43%, which represents a factor of about 4. Further improvements were found in regard to dormant deficiency, which considerably impacts CAD model alterability, and thus model robustness. Here the proportion of CAD models that contained type I dormant deficiencies was reduced from 71.62% to 48.91%. Fig. 1 shows a graphical summary of the proportions of CAD model deficiencies which fall into each of the main categories that are linked to assessment criteria and associated effect sizes, as discussed throughout the CAD model analysis and assessment presented in this paper.

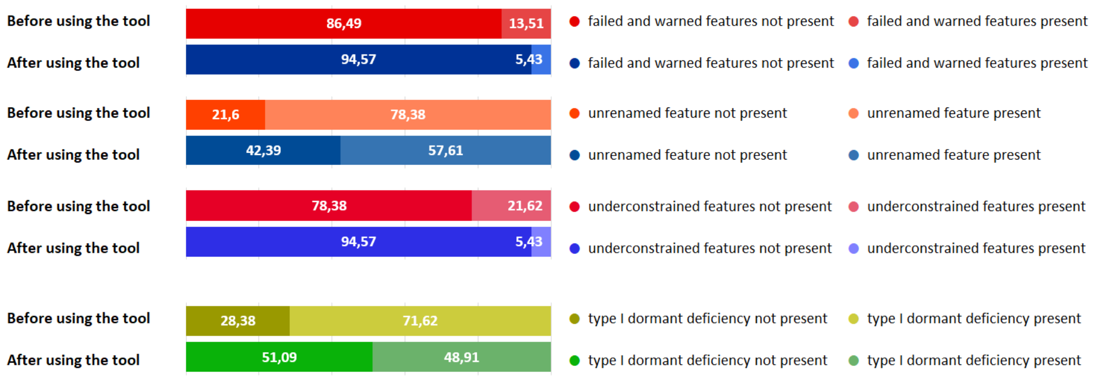

Fig. 1: Graphical representation of proportions of CAD model deficiencies (before / after feedback intervention) in each of the main categories that are linked to assessment criteria and associated effect sizes.

Based on the results of the CAD model analysis presented above, effect sizes for feedback intervention in each aspect of CAD model quality improvement – and thus improvement of the skills and competency required to create those more robust and best practice compliant models – were as follows. In the case of CAD models that contained features with warning / failure status (A1), the calculated individual odds yielded an odds ratio OR = 2.719. Thus, the overall odds that a CAD model would contain a deficiency that was related to a feature with warning / failure status were a little above 2.7 times as high for a CAD model that had been created by a student without feedback intervention as for a CAD model that had been created by a student with feedback intervention.

In the case of CAD models that contained un-renamed features (A2), the calculated individual odds yielded an odds ratio OR = 2.668. This means that the overall odds that a CAD model would contain a deficiency in the form of an un-renamed feature were a little below 2.7 times as high for a CAD model that had been created by a student without feedback intervention as for a CAD model that had been created by a student with feedback intervention.

As can be inferred from the analysis results above, the greatest effect size is in the case of CAD models that contain under-constrained features (A3). Here the calculated individual odds yielded an odds ratio OR = 4.800. Hence, the overall odds that a CAD model would contain an under-constrained feature were 4.8 times as high for a CAD model that had been created by a student without feedback intervention as for a CAD model that had been created by a student with feedback intervention.

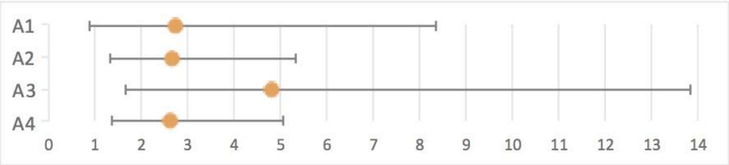

Fig. 2: Graphical representation of odds ratios and associated confidence intervals.

In the case of CAD models that contained type I dormant deficiencies (A4), the calculated individual odds yielded an odds ratio OR = 2.636. This means that the overall odds that a CAD model would contain a type I dormant deficiency were a little above 2.6 times as high for a CAD model that had been created by a student without feedback intervention as for a CAD model that had been created by a student with feedback intervention. Fig. 2 presents a graphical summary of odds ratios and associated 95% confidence intervals.

Assessment Criteria	Effect Size	
	OR	*d*
Features with Warnings / Failures	2.719	0.553
Un-renamed Features	2.668	0.542
Under-constrained Features	4.800	0.867
Type I Dormant Deficiency	2.636	0.536

Tab. 1: Assessment criteria and associated effect sizes.

Transforming the above reported effect sizes for dichotomous data based on odds ratios into their counterparts based on Cohen's d – the number of standard deviations representing a standard effect size measure (cf. [3]) – using the common conversion method described in [11] – yields the effect sizes shown in Tab. 1. Those effect sizes are not only above the $d = 0.4$ effect size which is regarded as necessary for any educational method or technology to be taken seriously (see also discussions in [5]), but also well-placed within the effect size range argued to be relevant for any feedback intervention (cf. [5,12]).

Conclusions:

Results obtained from the first part of this two-part study provide empirical evidence that the feedback intervention introduced in the reconstructed MCAD course was effective in improving the quality of the feature-based CAD models which students were able to produce through CAD laboratory activities and exercise assignments. The encouraging and reassuring outcomes achieved, based on the evaluation of empirical results from the study and compiled as responses to the research questions for the study, were as follows. Through intercommunication processes with the software tool (intervention agent), based on interactive human-computer communication with feedback in real-time, students can self-assess their current performance. That is, students are provided with metrics that can be used to compare their modeling outcome quality with that of an expected outcome. In particular, due to the novel concept of dormant deficiency, for the first time students in CAD education have a concrete measure which is explicitly associated with the robustness of feature-based CAD models. In addition to that, this software tool based educational intervention allows for the concept literally to become alive, thus giving students real-time experience of what the symptoms and effects of this kind of model deficiency look like in their own created CAD models. This, among other factors, engages students in various cognitive processes and actions, which eventually lead to a successful narrowing of the gap between actual and expected performance. This represents a promising step towards improving the outcomes of student performance in regard to creating feature-based CAD models that are both more robust and in better compliance with best practice. Furthermore, it reduces the gap between initial modeling skills and competency, and projected learning goals, as well as achieving the desired outcomes of learning from errors and benefiting from self-guided formative assessment supported by interactive feedback intervention.

The second part of this two-part study aims to shed some light on, and gain a better understanding of, the student perspective to this feedback intervention and its means of implementation. Therefore, parallel to the introduction of the software tool within the restructured CAD course, a student survey was conducted. Through this questionnaire-based online survey, students were given an opportunity to express their opinions about the newly introduced feedback intervention. That is, they were able to indicate what worked best for them and what did not work well. They were also given the opportunity to mention any shortcomings or omissions in the implementation, and to state what kinds of improvements they would like to see in this educational intervention. Analysis and assessment of the data obtained through this survey are currently in progress, with results expected to be published soon.

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