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PERCEPTIONS OF COACHING IN PRODUCT DEVELOPMENT TEAMS

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ABSTRACT
Contemporary global product development teams face increasingly ambiguous work environments. They are typically distributed, working in different organizations and in different time zones. They have different socio-cultural and professional-culture backgrounds. Individuals may speak different languages and the team may lack a common natural language. Within such scenarios, teams are still expected to produce quality products and bring them to the market in ever-shortened R&D cycles. Coaching product development teams in project-based courses and also in industry is gradually perceived as a response to team needs. In order to better understand how to maximally benefit from coaching, we developed a study based on a conceptual foundation of coaching [8] composed of five coaching roles carefully characterized to span the complete space of coaching activities. The context of this study was a project-based design course at Stanford University.
The study supports the following conclusions: (1) different stakeholders in the design process have different views regarding coaching; (2) the stakeholders' differing views change as the design stages progress; and (3) project success seems to correlate with some coaching style mix.

Keywords: Situated coaching, coaching styles, product development, teamwork, perception alignment, design education

1 INTRODUCTION
As product development (PD) becomes dispersed, multi-institutional, and multicultural, product development teams are formed on an ad-hoc basis to address emerging product needs and opportunities. These teams may need to produce quality design under stringent resource and time constraints. The role of a coach is emerging as a mechanism to support design teams in their complex task [2]. However, coaching in design processes is rather new to product development [1]. It is distinct from team leading or managing which is often performed by the project leader or manager. As part of the regular hierarchical organizational structure, team leaders are often tuned to the organizational goals and not necessarily to team social functioning. Attending to team social processes and needs could better be practiced by an outsider to the organization. Given that the seemingly mature field of leadership is fragmented and not without conceptual difficulties [8], it is not surprising that knowledge about the emerging field of coaching has been rather implicit and sometimes anecdotal. Moreover, even the terminology used to discuss the use of coaching in different settings is ambiguous [8]. Our goal is to support effective coaching in distributed work; first in an educational setting and subsequently in industry.
Therefore, we initially developed a conceptual foundation for understanding coaching [8] – consisting of the five roles *consultant, supervisor, instructor, facilitator,* and *mentor* – that could serve as a basis to make this knowledge explicit and subsequently accessible by others. In this foundation study, we empirically developed a characterization of coaching styles. Given the variety of coaching styles, it is hypothesized that appropriate styles change over time. More precisely, the coaching act is embedded in the particular context in which it takes place. The context and its evolution place particular demands on coaching. Therefore, coaching as we study it is *situated coaching*.

The context of this study is a graduate-level mechanical engineering course titled Team-Based Product Design Development with Corporate Partners (ME310) taught at Stanford University 1[6].[1] In this project-based learning (PBL) course, teams of three to five students work on unique, industry sponsored projects. These teams are supported by an individual coach through the whole course span of three academic quarters. Most coaches are graduates of the course who either are still enrolled at Stanford or work in local industry. All coaches are unpaid volunteers. Coaching has been extensively used as a tool in this and other courses [1][4].

In this paper we build upon the findings presented in [8]. Using the five coaching roles as a linguistic basis, we seek to elicit differences in perception of multiple process stakeholders as well as process dynamics in terms of perception alternations. Moreover, correlations between team (design) performance and coach behaviour are investigated.

Through this study, we aim to contribute to efficient coaching, primarily in educational but also in industrial settings. Such findings could lead to similar methodologies as developed by Wilde [13]. In his work, he describes how to establish efficient design team composition. Similar ideas might be feasible for coach-team composition, too.

This study is based on a questionnaire designed for this study to clearly fit into the context of the ME310 course to ensure maximum acceptance and relevance to the ME310 community. Terms, contexts, and behaviours are taken from the course environment. The survey was implemented as an official class assignment after two thirds of the 9-month course sequence to maximize the design process knowledge the students had already absorbed. Section 2 briefly reviews some dynamic properties of coaching in product design, Section 3 describes the research methods and Section 4 the results. Section 5 concludes the paper.

2 COACHING DYNAMICS IN PRODUCT DESIGN

Product development processes are dynamic: the project team, other participants (client [sponsor], coach, and management), the design task, and its external context (e.g., available technology or knowledge) continually evolve. This evolution must be understood and monitored to maximize the benefits of coaching. This section deals with several of these dynamic aspects: the subjective perception of coaching by the coaches and coachees, as well as the evolution of coaching as the design process unfolds. These are considered the most important to our context.

Coaching comprises at least two entities: coach and coachee. Even if both share terminology on coaching [8], it does not guarantee that both have similar perceptions on the coaching process. Conversely, from our observations in design coaching, we anticipate that different stakeholders would have different views about the importance of the coaches' roles, which in turn, might also result in diverging expectations and reactions in particular PD situations; for example, in addition to moral support, students might seek concrete, hands-on help. Yet, these expectations do not necessarily correspond to coaches' willingness to contribute. Diverging perceptions on coaching may harm quality, and increase cost and time of process and product. In this paper, we seek to develop means to elicit different coaching perceptions and understand their effects on process dynamics.

We chose the term *situated coaching* in order to express the need for specific, adopted coaching behaviour in different team, project and/or design situations and stages. From our experiences in project-based educational settings, we anticipate situated coaching to be a fundamental basis for coaching – and thereby team, project and/ or design – success. Similar ideas that also express the relevance of time in coaching can be found in other studies, too. Hackman and Wageman [5] developed a theory that is composed of coaching functions, times in which coaching interventions are likely to happen and would result in their expected outcome, and conditions under which team coaching would and would not improve performance. From their perspective, times most appropriate for coaching interventions are the beginning, midpoints, and ends of projects. Another study also focused on the life-cycle of teams and times most suitable for coaching interventions [3]. In contrast to Hackman and Wageman [5], they did select Tuckman's [11] stages as the basis for their analysis. For each stage, they list the functions most suitable for providing assistance. Other studies have examined coaching and related concepts of leadership and management [7],[8],**Error! Reference source not found.**[9],[10],[12]. For a detailed review of this literature consult [8]. However, only little relevance

[1] See also http://me310.stanford.edu.

is given regarding product design and related aspects of situated coaching. Even those studies that address aspects of situated coaching [3],[5] remain on a qualitative level. Quantitative aspects are not elicited. Our study seeks to remedy this situation by providing initial quantitative evaluations on situated coaching.

From Stanford PBL experiences we anticipate coaching situations, especially when they involve multiple contacts between coach and coachee, seldom to be static. They evolve as they unfold [1]. For example, trust between the parties develops, the role of the coach is better understood by the team and the coach, and working practices are formed. We consider this evolution to be a *macro-level* phenomenon of the situation. Different influences on macro-level situated coaching can be easily expressed by a multi-dimensional axis system. Possible axes are:

1. subdivision of design into successive stages (e.g., requirement definition, conceptual design, prototyping, detailed design)
2. team dynamics, for example, forming, storming, norming, performing (e.g., [11])
3. evolution of the coach-team relationship
4. collaborative, distributed team work
5. cultural divergence

To illustrate, design teams in an early design stage (requirement definition) encounter different problems and, thus, coaching needs than teams in later design stages. Similarly, project teams in the forming phase would benefit from other coaching behaviours than teams that are already in the performing stage. Changing coaching behaviour, expressed through evolving offers (by the coach) and needs (of the team), is also a result of items 3-5 above. Macro-level situated coaching presents challenges to coaches. These challenges, however, can be analyzed in advance and can be used to guide pre-emptive planning activities that allow all constituents to understand the situation. With our work, we hope to contribute to this by providing initial means for eliciting and understanding change of perceptions along the course of the coached design process.

In addition to aspects of macro-level situated coaching, there are local, dynamic changes that occur all the time in response to different factors, including the mood of the coach, the knowledge of the team and its progress, and project milestones. These fluctuations or environmental dynamics characterize the *micro-level* phenomenon of coaching. Micro-level coaching situations are harder to anticipate, since they arise in different unexpected ways. Experience and natural talent are the best resources for addressing such dynamic situations. Without them, failure or suboptimal coaching activities could occur. While this might be undesirable, it is sometimes unavoidable. Nevertheless, in numerous such situations, a coach’s intervention is not required in real-time. The coach can reflect upon the situation, seek assistance, and consult with peers. If it existed, a system including best coaching practices could be useful as well. The answer to these micro-level challenges lies in acting as a *reflective coach*.

3 RESEARCH METHOD

3.1 Research questions

From our context, a graduate PBL design class at Stanford University, we considered three stakeholders in the study of coaching perceptions: students, design coaches, and teachers. Based on our observations, we anticipated that different stakeholders would have different views about the roles of a coach. In this case, we perceived group perceptions and expectations as well as their articulation and exchange to play a crucial role. Only if the specifics of goals and perceptions are revealed and openly discussed, all stakeholders can develop a mutual understanding of coached design processes and thus contribute to their improvement. This led to the first question:

Q1: Do different perceptions of the coaching process exist between different stakeholders? If so, what are the differences?

In order to control the complexity of the initial research, we limited our analysis to macro-level effects, focusing on changing perceptions due to evolving design stages. We sought to gain insight into whether and how coaching perceptions change. Based on this and future work, means for improved situated coaching might be derived. In this context we asked:

Q2: Do perceptions of coaching change over the course of a design process? If so, what are the differences?

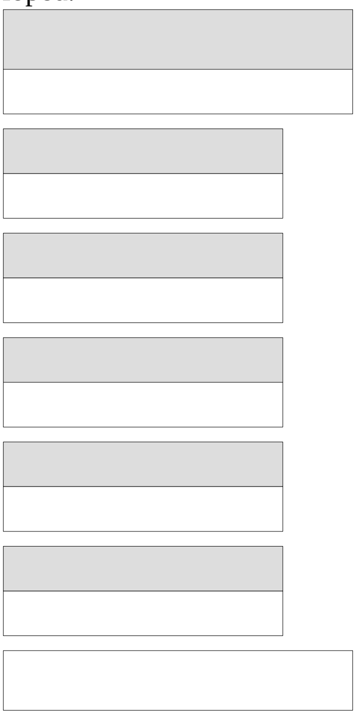
By introducing coaching to design settings in educational as well as industrial settings, additional resources are allocated. In order to efficiently use these resources and to identify major influence coefficients, coaching effort and related performance benefit need to be evaluated and understood. From our perspective, eliciting coaching perceptions of high and low performance coach-coachee contexts could help to do so. Therefore, in this study we sought to establish an initial, qualitative understanding of what characterizes successful design coaching by asking:

Q3: What is the correlation between design coaching and resulting team performance?

3.2 Questionnaire design

The basic structure of the questionnaire is illustrated in Figure 1(a). It consists of an imaginary design problem scenario (DPS) and descriptions of five different reactions (CR(a)–CR(e)) a design coach might have. Each of these reactions reflects one of the coaching roles (**c**onsultant, **s**upervisor, **i**nstructor, **f**acilitator, and **m**entor) developed by Reich *et al.* [8]. The role labels to the right of each coach reaction in Figure 1(a) indicate this reflection. Each coach reaction attempts to be stereotypical for its underlying coaching role through the expected choices of characteristics such as trigger (i.e., when coaching begins), social relation of coach and team, course of events which is typical of the coaching act, and goals of the coach. In addition, we asked the survey participants to give a short statement on the coach reactions they agreed with most and least, or to provide an alternate coach reaction (Q_{aCR}).

For each possible coach reaction, one question is posed ($Q_{CR(a)}$–$Q_{CR(e)}$). The question asks survey participants how much they agree with this specific reaction. Each question has to be answered on a Likert scale from 1 (strongly agree) to 5 (strongly disagree). We expected different perceptions of participating groups to be expressed in different degrees of agreement with one or the other coach reaction. In order to collect sufficient data for statistical analysis, six DPSs, each with five reactions, were developed.



(a) Conceptual structure of the questionnaire

	$Q_{CR(a-e)}$
Teachers	Would you like your coaches to behave in this way?
Students	Would you like your coach to behave in this way?
Coaches	Would you behave in this way?

(b) Survey questions for different groups

Figure 1: Structure of questionnaire.

To be able to elicit differences in perceptions according to design process dynamics, two design problem scenarios were constructed to serve as representative for each of the *early*, *middle*, and *final* design stages. Question Q_{DS} focused on whether or not participants perceived the scenarios to be in the intended design stage. Possible answers to question Q_{DS} are “early”, “middle”, and “final”. An example of one problem scenario appears in the appendix. It illustrates the structure of the questionnaire given in Figure 1.

In order to elicit different perceptions on coaching, the questionnaire design was slightly adapted to each of the participating groups: students, coaches, and teachers. Figure 1(b) lists the different questions $Q_{CR(a)}$–$Q_{CR(e)}$ regarding the respective coach reactions CR(a)–CR(e).
For statistical reasons, all coach reactions CR(a)–CR(e) of a DPS were randomized, meaning that their sequence changed with each DPS. In addition, the sequence of DPS presentation to participants was randomized. Due to the size of the student and coach group, two different questionnaire versions were developed for each group to achieve within-group randomization. Student grades for the first and second quarter were collected. We expected to draw conclusions on team performance and respective coach behaviour.
The survey was distributed to a total of 54 people: 5 belonged to the teaching team, 10 were design coaches, and the remaining 39 were students. Forty-seven complete and usable surveys were returned by teachers (5), coaches (9), and students (33) for an effective response rate of 87%. All teachers as well as all coaches are males. Four of the 31 students are females.

4 RESULTS

The General Linear Model (GLM) repeated-measures procedure was used for statistical analysis. Hypotheses about the effects of between-subjects factor *stages* (design stages of the DPS) and within-subjects factor *groups* (group membership of survey participants: students, coaches, teachers) were tested, in this case for one dependent variable: the agreement of the participants with respective coach reactions to the 6 DPSs. Course grades were considered as well.

4.1 Different Perceptions of Coaching According to Group Membership

Figure 2 presents the results related to question Q1. The rating is the average of group members across all DPSs. Errors bars denoting one standard deviation range are also given for each average. As can be seen, different perceptions of coaching seem to exist between the groups. None of the three groups voted identically with respect to all five possible coach behaviours. In addition to the mean values, standard deviations are presented. Since the amplitudes are large and overlap between groups, the results and interpretations from a graphical analysis have to be treated carefully.

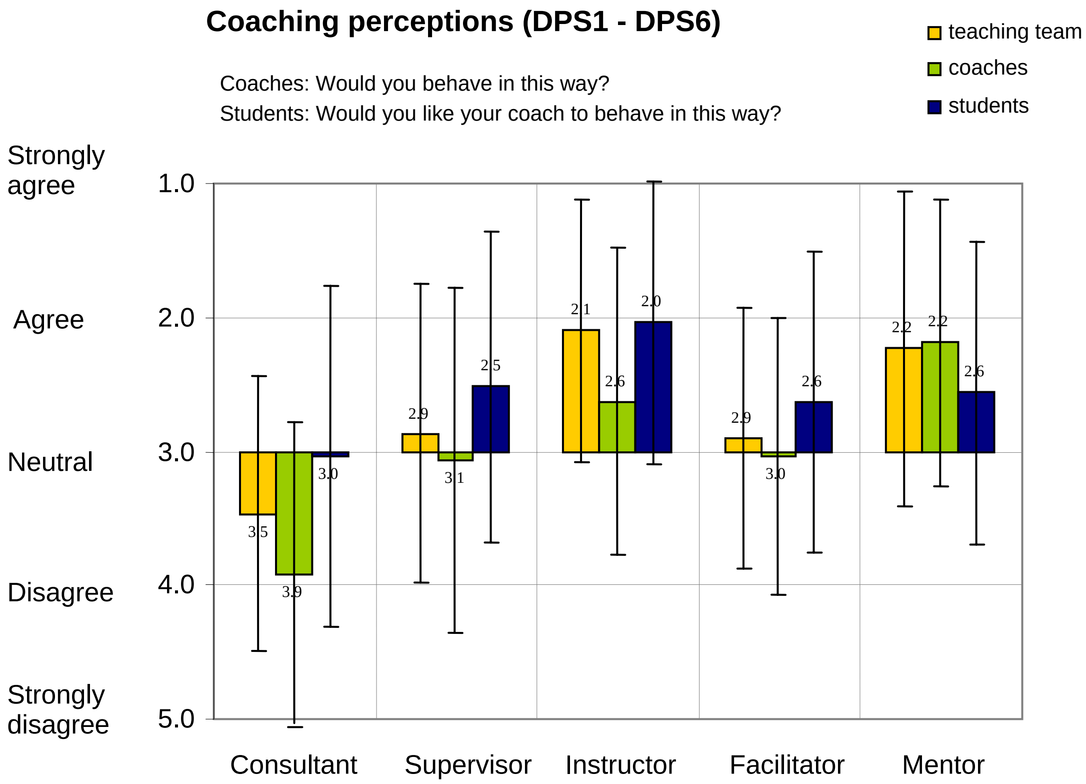


Figure 2: Differences in perception between groups (mean values).

In order to better evaluate the data, statistical tests were performed. Tests of between-subjects effects indicate that group membership (factor **groups**) has a significant effect on the dependent variable (sig.=0.018; Table 1). Post-hoc tests illustrated in Table 2 further detail that the mean ratings of coaches (C) and students (S) significantly differ (sig.=0.016). Post-hoc tests of contrasting mean ratings between teachers (T) and students as well as between teachers and coaches reveal significances greater than 0.05. This result may be due to the limited number of teachers participating in the survey. A more substantial data set could potentially lead to other findings.
Considering coaches and students to be the most crucial participants in coached design processes we conclude from the above analysis that different groups do have different perceptions of the coaching process. Thus, research question Q1 can be answered positively. The following paragraphs respond to the second part of research question Q1 and attempt to elicit fundamental differences in perceptions according to each coaching role. The basis for this analysis is the graphical evaluation presented in Figure 2, which has been enriched with personal statements collected in the survey.

Table 1: Test of Between-Subjects Effects (factor: groups [marked in bold])

source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	5909.98	1	5909.98	1322.77	.000
groups	39.37	2	19.68	4.41	.018
Error	187.65	42	4.47		

Table 2: Post-Hoc-Tests for Between-Subjects (factor: groups [marked in bold])

	(I) **groups**	(J) **groups**	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Bonferroni	1 (T)	2 (C)	-0.257	0.215	0.717	-0.794	0.280
		3 (S)	0.172	0.186	1,000	-0.291	0.636
	2 (C)	1 (T)	0.257	0.215	0.717	-0.280	0.794
		3 (S)	0.429(*)	0.146	0.016	0.065	0.794
	3 (S)	1 (T)	-0.172	0.186	1,000	-0.636	0.291
		2 (C)	-0.429(*)	0.146	0.016	-0.794	-0.065

One observation that can be drawn from the data in Figure 2 is that students rated all but the *mentor* role lower (agreed more) than coaches and teachers. For example, considering the *consultant* role, students clearly disagree less with this coach reaction. A possible explanation is that the *consultant* role comprises the largest work load for a coach. Coaches' statements also support this: "Most coaches don't have this much time…", or "coach is doing too much".
Although we expected the students to agree with the *consultant* role, they voted rather neutral. Explanatory student statements characterize this role as "helpful but [it often] leaves no room for the students to learn". Similarly, a teacher sees the *consultant* role as "too intensive, [it] solves the problem [and] does not contribute to [the students'] learning."
Rating values concerning the *supervisor* and the *facilitator* role are similar. Both roles are slightly approved by students. Coaches and teachers are undecided. Closer analysis of additional comments leads us to the insights that students expect a *supervisor* to "… provide options and tools" and that a *facilitator* "… helps but doesn't control". In comparison, coaches see both roles more reserved. Similar to the *consultant* role, the workload seems to be too high. Corresponding to the role of a *facilitator*, a coach states that all this is a "… learning process. A coach should help, not do the actual work." Another coach opinion of the *supervisor* role is that it simply is "… too much".
The most striking fact about the *instructor* role is that all participating groups agree with this coach behaviour, in particular the teachers and students. As students obviously want to learn, this role primarily fulfils their needs: "interaction & experience is key", "team learns a lot", and "enhances skills" (ME310 students). Teachers' agreement is understandable but at the same time could be questioned since this is their primary role. "Sharing knowledge" or seeing "the coach as an expert [teaching others]" is supported by coaches as well. However, critical coach statements expressing a "too abstract interaction" also occur and explain the data.
The *mentor* role is supported by all groups almost evenly. Students see this role as "encouraging" and "balanced". The *mentor's* "feedback [is] helpful" and he "acts wise". As relatively few social conflicts

arose in the first half of the course, the students' particular need for a *mentor* solving social problems did not necessarily occur and explains their reserved vote compared to the two other groups. Our potential explanation of the coaches' agreement is that the mentor role fits best with the particular ME310 situation, since the other coaching roles are already largely assumed by others. No corroborating statement can be found in the data, though. Most coach statements express behaviour "in a similar fashion". Evaluating the teachers' statements, aspects as "[the mentor is] addressing [the] overall project scenario", "[discussing] over coffee", or "listens" and "relaxed" emerge. Potentially, since none of the other roles addresses these aspects as clearly as the *mentor*, this role receives comprehensive support by members of the teaching team.

Observations stated above indicate that the five roles are well understood in their intended meaning. Statements that actually term the respective coaching roles correctly, e.g., "[the coach] acts as a mentor", support this conclusion.

4.2 Changes of Perception According to Situated Coaching

The questionnaire results related to changes in perception according to the three design stages are presented in Figure 3. As mentioned earlier, the results of 47 individuals were considered for evaluation purposes. Out of all participants, 43 associated both (out of six) DPSs correctly with the early design stage. Both of the middle stage DPS were recognized as intended by 29 participants. The respective number of correct associations for the final design stage was 13. Altogether 8 people recognized all six DPSs correctly according to the respective design stages. We assume that the falling number of correct associations was due to insufficient narrative DPS description regarding design stages. Moreover, the questionnaire was conducted after two-thirds of the ME310 course had elapsed, and the final design stage had not been experienced yet. Independent of the perceptions of the design stage, the following results refer to the design stages as intended in the questionnaire.

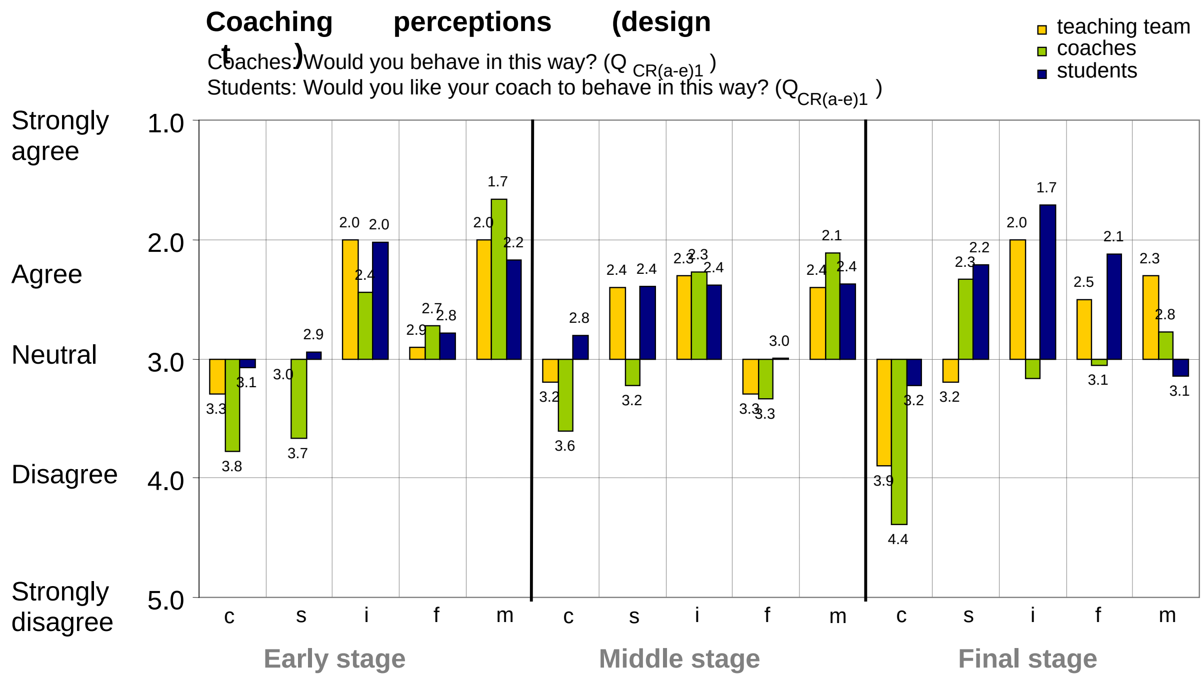


Figure 3: Changes in perceptions according to design stages (mean values).

Addressing question Q2, the interaction of stages and roles (**stages*roles**) reveals statistical significance (sig. ≈ 0.000, Table 3). Providing a more detailed evaluation, Table 4 presents pairwise comparisons of stages for each coach role. Except for the *instructor* role, the null hypotheses can be rejected in almost[2] all cases. Thus, we conclude that the perceptions on the *consultant*, *supervisor*, *facilitator*, and *mentor* roles change along the design process as described in the following paragraphs.

[2] Per role, at least two stage transitions out of three (early-middle, middle-final, early-final) reveal statistical significance.

Evaluating the results provided in Figure 3 yields the following observations. With respect to the *mentor* role, a noticeable descent from agreement to being neutral especially for students and coaches can be stated. Accordingly, we argue that the *mentor* role is of primary importance during initial team phases, e.g., in team building. Toward the end of a design project, time becomes an increasingly valuable resource and social issues are neglected. The teachers' constant ratings for all phases bolster this argument since they would naturally value *mentoring* even in the final phase of a project.

Table 3: Test of Within-Subjects Effects (GLM with stages and roles as repeated measures)

source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
stages*roles	Sphericity Assumed	48.66	8	6.08	6.56	.000
	Greenhouse-Geisser	48.66	6.19	7.86	6.56	.000
	Huynh-Feldt	48.66	7.73	6.30	6.56	.000
	Lower-bound	48.66	1.00	48.66	6.56	.014

*Table 4: Pairwise comparisons: stages*roles*

roles	(I) **stages**	(J) **stages**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval** Lower Bound	Upper Bound
1 (consultant)	1 (early)	2 (middle)	.175	.164	.292	-.156	.506
	1 (early)	3 (final)	-.457	.167	.009	-.795	-.120
	2 (middle)	3 (final)	-.632	.183	.001	-1.002	-.263
2 (supervisor)	1 (early)	2 (middle)	.526	.182	.006	.159	.892
	1 (early)	3 (final)	.620	.224	.008	.168	1.072
	2 (middle)	3 (final)	.094	.211	.658	-.332	.520
3 (instructor)	1 (early)	2 (middle)	-.157	.191	.414	-.542	.227
	1 (early)	3 (final)	-.139	.193	.476	-.528	.250
	2 (middle)	3 (final)	.019	.194	.923	-.372	.410
4 (facilitator)	1 (early)	2 (middle)	-.402	.173	.025	-.751	-.053
	1 (early)	3 (final)	.221	.172	.204	-.125	.567
	2 (middle)	3 (final)	.623	.164	.000	.291	.954
5 (mentor)	1 (early)	2 (middle)	-.346	.151	.027	-.652	-.040
	1 (early)	3 (final)	-.782	.195	.000	-1.177	-.388
	2 (middle)	3 (final)	-.436	.213	.047	-.867	-.006

Supervision and *facilitation* are requested (and provided) aspects of coaching toward the end of a project. Accordingly, argumentation for change of the ratings with respect to these roles goes along with the one expressed previously.

The importance of the *instructor* role is agreed upon by all groups over all design stages (exception: coaches in the final stage). Arguments stated in the answers to Q1 could be given again: providing instructions and imparting knowledge is a coach feature that is asked for during all design stages. This also explains the statistical analysis result.

With respect to the *consultant* role, students were neutral in all three stages, whereas the disagreement between teachers and coaches was consistent over the design process. Again, the correlation of time pressure and increasing workload toward the end of a design project might exceed a threshold of tolerance for coaches and teachers and may have led to the observed ratings.

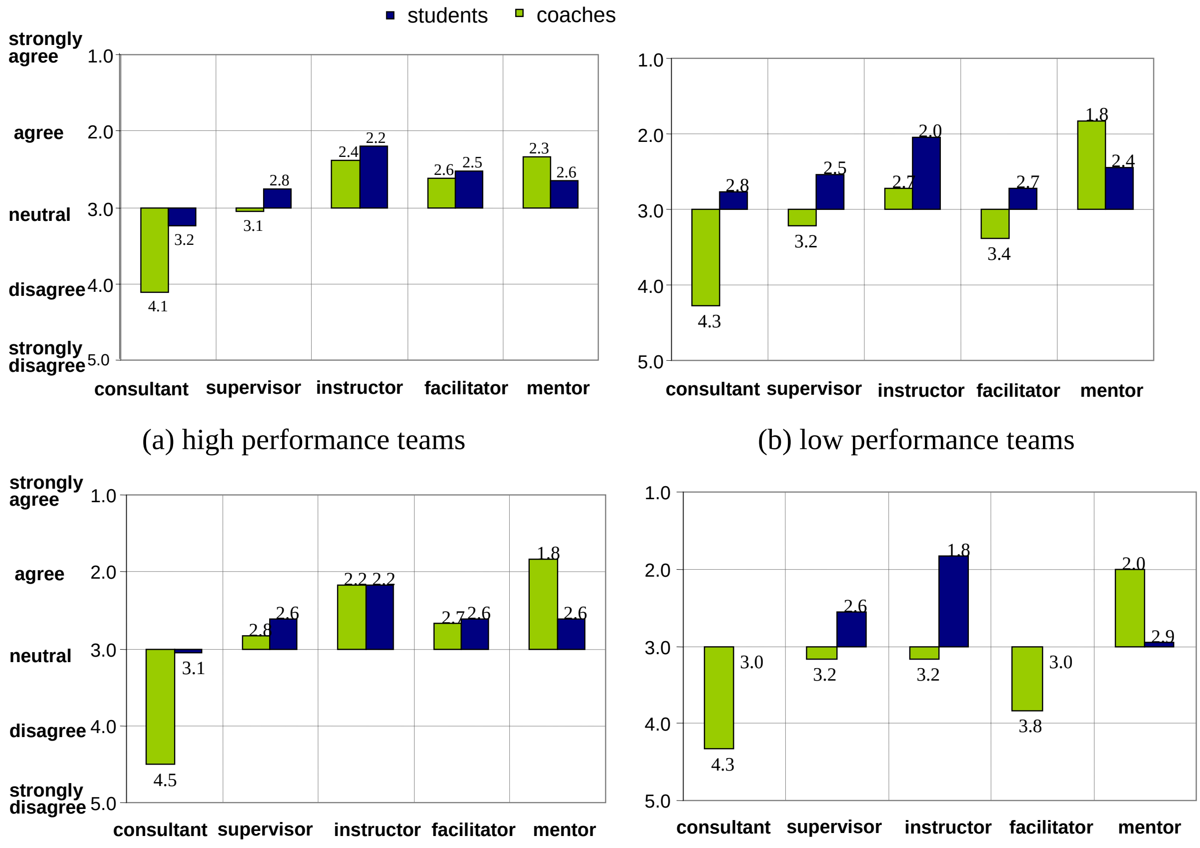
4.3 Correlation of coaching perceptions and design performance

In order to correlate team performance and coaching perceptions (research question Q3), specific team-coach relations were taken into consideration. Performance was assessed from multiple perspectives. For example, aspects such as requirement definition, project planning, prototype innovation and quality, product presentations, and documentation were be considered. One obvious measure that combines the mentioned criteria is the course grading. The correlation between coaching perceptions and team performance based on course grades is illustrated in Figure 4 (a and b). Due to the small sample, no statistical analysis to further address these questions was performed.

The perceptions of the three ME310 teams graded highest[3] and of their respective coaches are shown in Figure 4 (a); Figure 4 (b) illustrates the perceptions of the three ME310 teams graded lowest and of their respective coaches. All values are mean values. Assuming that the quality of team-coach relation and interaction influences team performance, we make the following observations. Considering all five coaching roles, the coaches of high-performance teams better satisfied their teams' needs. This was especially true for the *instructor* role. Here, high-performance team coaches better met the demands of their teams to fill the *instructor* role, whereas low-performance team coaches, on average, rather tended to be neutral. The divergence in perception is strengthened by the fact that low-performance teams agreed with the *instructor* role more than high-performance teams did. Identical observations can be made for the *consultant* role.

With respect to the *facilitator* role, high-performance teams agreed slightly more than low-performance teams. We argue that high-performance teams not only agreed more with the *facilitator* role but also demanded this particular behaviour from their coaches. As a result, high-performance team coaches, compared to their colleagues, agreed more with that role and, thus, responded better to their teams' needs. Another clear observation can be made regarding the *mentor* role. While high-performance team coaches did see their primary function in being a *mentor*, a *facilitator* and an *instructor*, low-performance team coaches almost exclusively saw their role in being a *mentor*.

Respective team demands for high and low performance teams were almost identical and rather neutral. To elaborate on these observations, two single team-coach relations are illustrated in Figure 4 (c and d). Figure 4 (c) provides data regarding the ME310 team ranked second, Figure 4 (d) illustrates data on the eighth team (out of nine) according to the mean values of team grades. Again, the coach of the high-performance team obviously saw his position as being not only in the *mentor* role but also in the *supervisor*, *instructor*, and *facilitator* roles. In comparison, the coach of the low-performance team tended to disagree with all but the *mentor* role.



(a) high performance teams

(b) low performance teams

(c) high performance team

(d) low performance teams

Figure 4: Correlations between coaching perceptions and team performance. The Coaches' question was 'Would you behave in this way?' and the students' question was

[3] Team grade was the mean value of team grades from the first and second academic quarters.

'Would you like your coach to behave like this?' for (a) and (b) and 'Would you like your coach to behave like this?' for (c) and (d)

Summarizing these results, we argue that if a team is inferior, a solely *mentor* support is insufficient to secure successful design project outcome in the educational context of ME310. Instead, a more comprehensive and broader spectrum of coaching is needed. As discussed above, besides being a *mentor*, coaches should also act as *supervisor* and *facilitator* and, especially, as an *instructor*. In general, coach and coachee perceptions should be aligned in order to achieve maximum team performance.

5 CONCLUSION AND FUTURE WORK

With the role of coaching assuming an increasingly important role in project-based courses and also in industry, it is critical to understand how maximally to benefit from coaching. Based on a conceptual foundation of coaching [8] composed of five coaching roles carefully characterized to span the space of coaching activities, we developed a study in the context of a project-based design course at Stanford University. The study supports the following conclusions:

1. Different stakeholders in the design process have different views regarding coaching.
2. The stakeholders' differing views change between different design stages.
3. Project success seems to correlate with some coaching style mix.

These results shed light on a previously informal understanding of coaching in product design. More specifically, with the objective to develop broader and explicit knowledge on coaching, we utilized the five coaching roles *consultant*, *supervisor*, *instructor*, *facilitator* and *mentor* to answer three major research questions. First, since we presume the existence of differences in perceptions of the coaching process between multiple stakeholders, we asked whether these different perceptions really exist and what their respective characteristics are. Second, drawing parallels from design and team processes, we assume coaching to have an unfolding and evolving nature, too. Framed under the term *situated coaching*, we asked whether perceptions of coaching do change along a coached design process and, thus, whether they are indicators of process dynamics. Third, in order to elaborate an initial understanding of what characterizes successful coaching, we considered different aspects of team performance and examined correlations.

By developing and applying a questionnaire-based survey, we collected sufficient data in the educational environment of a design course at Stanford University to answer our research questions. Graphical as well as statistical analysis yielded the insight that multiple, different perceptions of a coached product development process do indeed exist and even evolve over time. We found that coaches see their primary function in being a mentor, whereas design students additionally asked for supervision, instruction and facilitation. Through the consideration of performance data, we were able to address questions of successful, high-performance coaching, at least to a preliminary degree. From our analysis we conclude that in successful coaching design coaches realize multiple roles, such as those of an *instructor*, *facilitator*, and *mentor*. Furthermore, effective coaching is characterized by only marginal differences in perceptions between coach and coachee, meaning that the coach better satisfies the coachee's needs.

Future implementations of coached product design processes could incorporate the findings stated above. Thus, coaching process participants need to know about potential differences in perception and their change over time. At best, these specifics are addressed before and during the coached design process. Additionally, implementing our findings could foster knowledge-imparting behaviour of design coaches or, more generally, could broaden the coaches' attitude from an exclusive mentoring style to a more multi-faceted spectrum. In this regard, students might also be encouraged to ask for different coach behaviours.

Lastly, two aspects of future possible applications of our survey are proposed. On the one hand, the questionnaire could be employed to teach and train coaches who are either new to the specific environment or novices to coaching in general. By completing the questionnaire and having a subsequent discussion of possible questions, suggestions, and results, novice coaches might get the chance to develop competence in a protected environment, at least to a preliminary degree. Experienced coaches and coachees could be facilitators for this process and, in doing so, enrich the exchange of expertise. On the other hand, preceding the establishment of a coach-coachee relationship, the questionnaire could also be employed to elicit individual as well as group profiles that would allow for effective coach-coachee configurations. A similar procedure is already successfully used to establish efficient design team compositions [13]. Therefore, further research is required to understand successful high performance coach-coachee interaction.

The final transition into distributed collaborative design team work needs further investigation, too. Aspects such as multiple coaches who might be distributed or a single coach allocated at either a local or another third remote site must be considered, and possible effects on coach-coachee relations elaborated. Future work could also involve developing support material or even a decision-support system for managing coaching in projects. The relevance of our findings to industrial settings is also not clarified yet. Potential analyses in industrial projects, maybe even applying the questionnaire, might lead to similar or other, potentially more useful, findings for the design research community.

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APPENDIX

<table>
<tr><td rowspan="1">DPS</td><td colspan="2">Team ”Aloha - Surfboard Structural Dynamics” has to deliver a first draft of the final prototype in two days. The team made interesting changes to the board structure during the last two quarters. Since these changes - according to the statement of an expert engineer - promise to help minimize the structural deformation, the team needs to obtain quantitative analysis results, e.g., from a FEM simulation. Without such a simulation, it will be difficult to convince anyone in the teaching team of the innovative nature of the board design for the final prototype. Unfortunately, no one on the student team is an FEM expert. However, the coach has extensive theoretical and practical expertise in the field.</td></tr>
<tr><td rowspan="10">coach reactions</td><td>CR (a)
(f)</td><td>The team does not consider the FEM simulation to be too important. However, the team asks the coach for help with the given problem. The coach decides to provide the team with a workstation that has an FEM software package installed on it, and offers them some minor help during the software usage.</td></tr>
<tr><td>$Q_{CR(a)}$</td><td>Would your coach behave like this?
☐ strongly agree ☐ agree ☐ neutral ☐ disagree ☐ strongly</td></tr>
<tr><td>CR (b)
(m)</td><td>The team talks to the coach about this problem. The coach does not see any possibility to reach the goal of a serious simulation in the short time left and suggests presenting the prototype without any simulation. The coach further encourages the team not to worry too much about that and affirms that the teaching team will not insist on an FEM simulation if the students present a promising prototype.</td></tr>
<tr><td>$Q_{CR(b)}$</td><td>Would your coach behave like this?
☐ strongly agree ☐ agree ☐ neutral ☐ disagree ☐ strongly disagree</td></tr>
<tr><td>CR (c)
(i)</td><td>The coach realizes the problems of the team and initiates an immediate team meeting. In that meeting the coach teaches the team how to use one particular software tool that does simple dynamic FEM simulations. During the simulation itself, which is conducted by the team, the coach answers any questions about the software.</td></tr>
<tr><td>$Q_{CR(c)}$</td><td>Would your coach behave like this?
☐ strongly agree ☐ agree ☐ neutral ☐ disagree ☐ strongly disagree</td></tr>
<tr><td>CR (d)
(c)</td><td>The team addresses the coach to help them with the simulation. Due to the team’s urgent and critical need, the coach agrees to help, takes the CAD model generated by the team and makes a simple but meaningful dynamic simulation. The next day the coach presents the team with the results and answers all the questions the team has.</td></tr>
<tr><td>$Q_{CR(d)}$</td><td>Would your coach behave like this?
☐ strongly agree ☐ agree ☐ neutral ☐ disagree ☐ strongly disagree</td></tr>
<tr><td>CR (e)
(s)</td><td>The coach realizes the problems of the team and initiates a team meeting. To that team meeting the coach brings along three software packages that would allow them to make a relatively easy and quick dynamic FEM simulation. The coach tells the team about some of the software characteristics of each package, outlines the general rules one should follow to receive reasonable results, tells them where they can find additional information and then leaves any further action to the team.</td></tr>
<tr><td>$Q_{CR(e)}$</td><td>Would your coach behave like this?
☐ strongly agree ☐ agree ☐ neutral ☐ disagree ☐ strongly disagree</td></tr>
</table>

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