# Three studio critiquing cultures: Fun follows function or function follows fun?

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***Abstract:*** *For the longest time, design was an activity with no distinction among disciplines. Over time, separate design disciplines had formed their own cultures and their own educational practices. In this paper, we use data from a limited set of design reviews along with a literature survey to conduct a comparative analysis of contemporary reviewing and critiquing cultures in architecture, industrial design and mechanical engineering. We point out differences and communalities, and conclude with a list of the lessons the three disciplines can learn from one another regarding reviewing in the classroom. We dwell especially on one issue that currently differentiates the three cultures: the stress they lay on excitement and fun. We believe that a world in which products of all sorts – from buildings through machines to consumer products – are fun, is a better world to live in.*

**Keywords:** architecture, critique (crit), design, fun, industrial design, mechanical engineering, review, studio, teaching profiles

## 1. Introduction: The studio

During the Renaissance, design reached an unprecedented peak, and began establishing itself with a separate identity – no longer part of art or the crafts. This was, at least partially, a result of the ability to detach conception from execution, largely owing to the invention of orthogonal projections (Heidenrich & Lotz 1974). Armed with this representational method, designers could describe and specify the objects and spaces they imagined and the ensuing documents could be sent to the site or workshop for execution. Architecture, and later engineering (and much later industrial design), acquired the status of independent professions, which eventually led to the establishment of formal education in these disciplines. This is not the place to expand on the history of design education, but we would like to point out that formal professional training in architecture was instituted as early as 1671 at the *Academie Royale d'Architecture* in Paris. By 1819, when the *Ecole des Beaux Arts* opened its gates in Paris (Carlhian 1979, Egbert 1980), technical schools that taught architecture and/or engineering had opened in Prague, Vienna and Berlin, and during the 19th century, they reached many other places in Europe, North America and beyond. Despite the short period of their activity, curtailed due to political circumstances, the *Bauhaus* (1919-1933) and

*Vkhutemas* (1920-1930) were, as is widely agreed, turning points in the history of architecture and design education (Bojko 1980, Forgács 1995).

The *Normal School of Design* – later the *Royal College of Art* – an early school of industrial or product design, opened in London in 1835 (Quarante 1994). Even so, many industrial designers until quite late in the 20th century were architects, and formal training, when not embedded in art, often sprung from schools of architecture.

The first school for military engineering was set up in France in 1749 and had a crucial influence on the *Ecole Polytechnique,* founded in 1794, which had programs in engineering and architecture alike (a school of bridges and highways was established even earlier, in 1775) (Ferguson 1992). It was followed by the *Ecole Centrale des Arts et Manufactures*, founded in 1829, a leading engineering school. A year later West Point became the first engineering training program in America. In England, a chair of engineering at Cambridge University was established only in 1875, although non-degree courses in engineering had already existed earlier, e.g., at the University of Glasgow (Barron 2009). Engineering educators wanted to shift the basis of their trade from craft and trial and error to methods based on a combination of technology and science, especially mathematics; this approach dominated mechanical engineering education until not long ago (Dym et al. 2005).

All of these schools offered practical training, fortified by scientific and general studies. In most cases they included a project-based practicum component. In the *Ecole des Beaux Arts* the practical work was undertaken in the atelier, French for studio. All modern educational programs in design and architecture, have inherited the studio and still maintain it as a central component of the training they provide. In engineering, the term studio is not frequently used, but we shall use it in the engineering context as well, meaning the environment in which students, individuals or teams, work on their practical project assignments. In all cases the studio is where design is learned by practicing it in a 'hands-on' fashion.

Nowadays, the studio consists of a group of students who meet regularly with one or more teachers who guide their work on given assignments, usually in a designated classroom (also called "the studio"). Most of these meetings are dedicated to design reviews of various kinds, contingent on the assignment and teaching format. The most prominent review types are: a personal critique session, a group review, and a jury assessment session.

The personal critique (crit) is a conversation between a teacher and an individual student or a few students who work together as a team. The crit is an informal setting in which progress in the project is presented and discussed, and issues relevant to its further development are considered. Sometimes peers participate in a personal crit, mostly as listeners only. The design crit is the 'bread and butter' of the studio activity, and possibly of the entire design education (Goldschmidt 2002). Several researchers have analyzed and assessed the crit; for example, Cardoso et al. (2014) have centered on question asking during the crit.

In a group review all students participate (actively or passively) in critiques of all of their projects, which are presented and discussed one after the other. Other professionals, beside the teacher(s), are sometimes invited to participate in the review, which may be more or less formal. Reviews are usually scheduled as phase completion markers in the development of projects (Oh et al. 2012).

A jury is a formal review at the end of the assignment. Students present their finished projects, which are consequently discussed and assessed by a jury consisting of invited professionals. The teacher may or may not take part in the jury commentary (Anthony 1991).

In this paper, we compare the three design disciplines: (mechanical) engineering, industrial design and architecture, based on empirically collected data and a literature review[1]. Our intent is to extract the best practices in each discipline that can be transferred to the other

disciplines as well. One aspect that does not come up in the literature but caught our attention in the data, was the attitude of reviewers towards the 'fun' component of design, also referred to as 'exciting' and 'cool' design (an exception is Lande et al., 2014. Their study identified the stress on passion in industrial design studio crits). Christensen and Ball (2014) found that aesthetics is an important creativity evaluation criterion in industrial design, along with functionality and originality. The aesthetic dimension of a product is closely related to 'fun'. This corroborates the experience of the authors as designers and design teachers. We think that fun, although only one of many aspects that we handled in the comparison, deserves special attention, because although it stands out it is often ignored by 'serious' research. We therefore treat it as equal to other design aspects in our findings, but we emphasize it in our conclusions. Thus, we hope to contribute to the still meager basis of design education pedagogy.

## 2. Literature review and research questions

The literature survey below refers to the studio educational system under three headings: studio learning objectives; crit and review contents and purpose, and pedagogical strategies. The section ends with six research questions.

### 2.1 Studio learning objectives

The design education literature in the various disciplines emphasizes the learning of design skills that is meant to be facilitated in the studio. The engineering literature spells out what these skills are (EC-2000 [Engineering Criteria 2000], issued by ABET [Accreditation Board for Engineering and Technology], criteria 3a-3k), e.g., the ability to function effectively in teams; effective communication; the ability to engage in life-long learning and understanding the global and social contexts of engineering solutions (Besterfield-Sacre et al. 2000, Woods et al. 1997). Assessment in engineering is to be carried out using a checklist that emphasizes completeness in light of the goals (e.g., Besterfield-Sacre et al. 2000, Felder & Brent 2003). Other researchers also draw attention to the importance of the situational nature of design and its cultural and disciplinary contexts (e.g., Brandt et al. 2013, Carvalho et al. 2009), which must find their way into the studio. Yet others list more traditional skills that must be developed, such as the outlining of needs, generating alternatives, employing selection techniques, developing models, performing analyses and explaining results (Frank et al. 2003). Atman et al. (2003) add developing prioritizing criteria, bounding the design episode and creating stopping rules. In the architectural literature we find additional types of skills, such as the command of a dual representational language that is both verbal and graphic (Schön 1981), and the need for attention to the precise local context of a design intervention (Meyer 1991). The industrial design literature emphasizes Schön's reflection in action (Valkenburg & Dorst 1998) as a major objective, which is shared by other design disciplines. In the context of industrial design, Brandt et al. (2013) stress the experimental nature of studio work, allowing students to gain direct experience with form, functions and materials. They also emphasize the contribution of the studio experience to the creation of students' professional identity – socialization into the profession. Communication skills are of the essence in this respect (Dannels et al. 2005). Ledewitz (1985) claims that students must master "thinking architecturally", but she does not explicate what such thinking means. Similarly, Cross (2006) asserts that there are "designerly ways of knowing" that students in all design disciplines are expected to adopt as they develop their design skills in the studio.

Along with skills, the literature suggests that the studio also is where knowledge should be conveyed, from experts (teachers) to students, but also from students to other students (Oh et al. 2012, Cennamo et al. 2011). Adams et al. (2014) use PCK (Pedagogical Content

Knowledge) to expose the content knowledge that is being transmitted in design reviews. However, some of the literature, especially in engineering, reflects a current tendency to minimize the role of formal knowledge diffusion by teachers. The claim is that students must gather information and form knowledge by themselves and take responsibility for doing so (Smith et al. 2005, Woods et al 1997); the teacher should engage in knowledge transmission only upon students' requests (Marra et al. 1999).

### 2.2 Pedagogical strategies

Not much has been written about design teachers and their performance. To date, most design teachers are recruited from amongst practitioners, and they receive no formal training as educators. Quayle (1985), who has written a guidebook for design teachers, classified teaching modes and teaching roles, of which she lists six: the expert, the formal authority, the socializing agent, the facilitator, the ego ideal, and the person. Goldschmidt (2002, Goldschmidt et al. 2010) has consolidated these into three profiles: source of expertise/authority, coach/facilitator, and 'buddy'. The latter is a supportive and encouraging figure, which caters to the student's emotional needs but also serves as a role model and professional socialization agent. Ochsner (2000) and Çikiş and Çil (2009) take a psychological stance, noting that design teachers have to draw on their own experiences as former students. They compare the relationship between teacher and design student, which is often very charged owing to a strong emotional attachment of the student to his or her design, to that of a psychoanalyst and a patient. The ultimate goal is the patient's independence, as also stressed by Winnicott (1971), which is analogous to the situation in the studio wherein the student eventually learns to act independent of the supporting safety net the teacher provides when necessary.

In architecture, Ledewitz (1985) spelled out six particular teaching strategies aimed at developing students' design skills. She mentioned experimenting in multiple design cycles; beginning backwards – first devising a solution and only then adjusting it to problem requirements; incremental information dispensing of information, which lends different problem foci at different stages; studies of solution types; form experiments; and finally, self-evaluation. Many experienced design teachers have personal repertoires of strategies that they had tried out and found to be effective over the years. In architecture, Morris (1966) talked about the difference between duplication (of existing solutions) and the discovery of new possibilities – a more meaningful way to learn how to design. We may compare this approach, which is shared by many educators, to the distinction made by Gestalt psychologists between reproductive and productive thinking in problem solving (Wertheimer 1959). The former pertains to solving problems that resemble other problems with known solutions, by repeating similar procedures. When the problems are new and unfamiliar, this is not possible and the problem solver must interpret the problem in a novel – productive – way, which leads to a new, original solution. Studios vary in their stress on the problem as opposed to stress on solutions (Gero & Jiang, 2014). In the architecture literature, we also find attempts to portray 'best practice' in design teaching. For example, Attoe and Mugerauer (1991), who interviewed award-winning design teachers, identified 14 factors they considered effective in studio teaching, clustered into three groups: the teacher as self, personal style, and course format. In a similar vein other writers dwell on the predominance of teachers' own experience and style (Goldschmidt et al. 2010), sometimes referred to as a 'black box' (Sipahioğlu 2012).

The industrial design literature paid little attention to teacher-student relationships and their pedagogical consequences (Cennamo & Brandt 2012). Generally, coaching and facilitating are considered the model for instruction (Brandt et al. 2013). An exception is a study by Cennamo et al. (2011) which underpins specific design teaching strategies. For

example, they recommend dispensing specific assignments, taken from or mimicking reality, to be accompanied with what they call meta-discussions in the studio; explicit prompts and reminders are a positive strategy; and in their role as coaches teachers should model design acts to the students. The proposal to hold meta-discussions in class recalls single and double-loop learning, which is a theory of action by Argyris and Schön (1974). They claimed that people's behavior when encountering a new situation is guided by governing variables (beliefs, values and principles) and action strategies (governing their de facto behavior in a given situation) that can be consolidated into single or double loop learning. When no unintended consequences are encountered, it is enough to apply one's established action strategy to arrive at a solution. This is single-loop learning. However, if unintended consequences are detected, one must visit one's governing variables to check their validity in the given case. Sometimes values and beliefs must be adjusted to new realizations. Then new action strategies can be developed towards achieving a novel and satisfying outcome. This is double-loop learning. Argyris and Schön (ibid.) claim that double-loop learning is deeper and addresses fundamental issues that can bring to change and growth; in the design studio, meta-discussions often target such personal growth.

In engineering design, the knowledge-based scientific approach has shifted towards a problem, or project-based learning (PBL) paradigm, which has been formalized in the U.S in 1996 in document EC-2000. Europe, where an important concern has always been the adaptation of engineering education to the requirements of industry (especially in Germany), followed suit soon thereafter (e.g., Frank et al. 2003). The paradigm shift is well documented in several publications (e.g., Dutson 1997, Dym et al. 2005, Felder & Brent 2003), and accounts of successful applications of the principles of EC-2000 can be found in the literature. A case in point is Stanford University's ME301 course, which has served as a model for a number of similar mechanical engineering courses around the world (Lande & Leifer 2010). Barrows (1996) spells out some of the strategies that are responsible for the effectiveness of the PBL approach: the class is student-centered; work is carried out in small groups (see also Smith 2005); assignments are experience-based (hands-on) and based on problems; assessment is skill-oriented (as opposed to knowledge-oriented) and the process is self-learning oriented. Work in teams is of particular importance, which is not usually the case in architecture or industrial design. The PBL paradigm is in perfect alignment with the Design Thinking method that has swept through the design world in the past decade in response to the innovation drive of businesses (Brown 2009). It is well suited to the needs of industry and is considered a successful development in engineering design education. Being aware that engineering students now learn to design in an environment that we refer to as a studio, we may possibly understand this development as the realization of the legacy of Donald Schön, who had this to say as early as in 1985:

"I shall argue that the schools of other professions have a great deal to learn from the unique institution of architectural education, the studio… increasingly, leading practitioners and educators in these professions have become aware of the crucial importance of intermediate zones of practice which do not lend themselves to the theories and techniques derived from the normative [science-based] professional curriculum… They have begun to shift their attention from technical expertise to artistry and from problem-solving to problem setting." (5)

### 2.3 Crit and review contents and purpose

The shrinking role of knowledge transmission in the studio raises questions regarding the purpose, contents and format of crits and reviews, and as a derivative, the role of the teacher[2] is also less clear than it had been when the students' work in the studio still resembled an apprenticeship to a certain degree. Students have a 'license' to experiment and explore (Schön

1983), and while their design repertoires and knowledge are still limited, they benefit from feedback and help in assessing the consequences of their design acts. The teacher thus inevitably offers a response to the student's work. Most of the literature recommends that in doing so, the teacher should act as a coach. Schön, a strong proponent of the coaching model of design instruction, described coaching as consisting of listening, telling, demonstrating and imitating (1987). The latter is geared toward learning from the accumulative experience embedded in precedents and other references, thus developing a repertoire of solutions (in addition to a historic and cultural awareness). According to Uluoğlu (2000), coaching (in architecture) must include demonstrating how to perform design acts, describing and interpreting design situations, considering alternatives, enhancing communication, and more.

The question of values and belief systems, not to mention hidden agendas and ideologies (Ward 1990) held by teachers and whether they should impart them to students is also raised in the literature, along with the issue of hegemony in the studio, especially in industrial design (Hsiao & Cheng 2006), but also in architecture. With the shifting of the teacher's role to coaching, he or she is seen less as an authority figure but rather a facilitator in a democratized studio, and therefore a teacher's hegemony is not considered positively. At the same time, it is acknowledged that teachers have stances and ideologies that they can share with students, as long as students remain free to form their own opinions and positions. This may be regarded as part of the professional socialization process that takes place in the studio.

Another major issue the literature entertains is the tension between a focus on the design process, versus an emphasis on the design outcome, or product. In architecture, Utaberta et al. (2011, 2013) give clear precedence to the process in feedbacks offered in the studio. de la Harp et al. (2009) found that in design and architecture studios (as well as art), assessments centered on process rather than product. Dannels et al. (2008), who are communication researchers, explained the importance of communication skills in industrial design, which should be acquired in the studio. Among others, they pointed out that design students must be able to explain the rationale for their choice of concepts and their processes, on top of presenting their products. Goldschmidt (2003) added the need to look at the person: how much progress has the student made, is there evidence of learning, and what the creative potential of the student is.

Based on the literature, and with insights the authors possess as designers and design educators, we have developed the six research questions that follow. We shall not attempt to answer them directly through the empirical study we conducted; rather, in the conclusions chapter we answer them in conjunction with that study.

*Research questions*

Q.1 Are skill building and knowledge transfer evident in studio reviews?
Q.2 What takes precedence: product performance or a fun/exciting outcome?
Q.3 What are the teaching profiles of teachers and external reviewers?
Q.4 Is learning augmented by meta-discussions in final reviews?
Q.5 To what extent are teachers involved in the development of students' design projects?
Q.6 Do reviews focus on the design process? On the design product?

## 3. Research method

### 3.1 Data

Our research is based on the data provided by Purdue University, to which we added protocols of two architectural design studios collected earlier at Tel Aviv University[3]. Since our aim was to compare the review cultures in three disciplines: Industrial design (ID: Junior

– IDJ, Graduate – IDG), mechanical engineering (ME), and architecture (ARCH), we chose comparable sessions from those disciplines, as shown in Table 3.1.

Table 3.1 Review sessions that were analyzed

**ARCH** — **Meeting**

| | **1** First | **2** Second | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Students | Teacher 1 | Teachers 1, 2 | | | |
| ARC.Student 1 | x | x | | | |
| ARC.Student 2 | x | | | | |
| ARC.Student 3 | | x | | | |

**ME** — **Meeting**

| | **1** Prelimin. design | **2** Concept design | **3** Final design | **4** Competition* | **5** Final debrief |
|---|---|---|---|---|---|
| Students | | ME Teacher | ME Teacher | Jury | ME Teacher |
| Robot fish team | | x | x | | x |
| Prop team | | x | x | x | x |
| Other students | | Present | | | Present |

**ID Junior** — **Meeting**

| | **1** First | **2** Second | **3** Client | **4** Look like | **5** Final |
|---|---|---|---|---|---|
| Students | IDJ Teacher | IDJ Teacher | Clients | IDJ Teacher | Clients |
| Adam | | x | x | | x |
| Alice | | x | x | | x |
| Sheryl | | x | x | | x |
| Other students | Present | | | | Present |

**ID Grad** — **Meeting**

| | **1** Search | **2** Concept | **3** Client | **4** Concept reduct. | **5** Final |
|---|---|---|---|---|---|
| Students | IDG Teacher | IDG Teacher | Clients | IDG Teacher | Clients |
| Mylie | x | x | x | | |
| Dan | | | | | |
| Sydney | x | x | x | | |
| Eva | | | | | |
| Walter | | x | x | x | |
| Other students | Present | Present | | | |

* Session 4 in ME (jury) was scored qualitatively only, by one researcher.

### 3.2 Questionnaire

We formulated a questionnaire aimed at estimating the prevalence of behaviors in the sessions we chose to analyze (Table 3.1). The questionnaire included four categories: reviewing model, task construal, design process and evaluation, and studio ambiance. The questions were composed based on the Purdue dataset, the authors' experience as expert design educators, and the literature. With use, the questionnaire was refined: we made changes such as merging similar questions, moving questions to other categories, adding questions, and deleting questions that did not appear to be sufficiently relevant. Altogether, the questionnaire now includes 31 questions.

Each question was scored on a Likert scale of 1 to 5, where 1 is low prevalence and 5 is high prevalence. All four authors scored jointly some of the sessions; pairs of authors scored the remaining sessions. Any disagreements were discussed until agreement was achieved. A N/A (Not Applicable) reply was also possible (see note under Table 3.1 regarding ME session 4). Results were entered into an excel sheet and averages were computed where relevant.

The questionnaire and scores are presented in an appendix. Later we translated averages, or direct results, into four categories: High, Medium-high, Medium-low, Low. These are the

scores reported in the findings section. Given the small sample, no statistical analyses were attempted.

### 3.3 Literature review

In parallel, we conducted an extensive literature review, presented in section 2. In the conclusions, we mapped the results of the empirical analysis – the questionnaire – onto the themes we inferred from the literature.

## 4. Findings and discussion

The findings in this research are based on our questionnaire, as well as qualitative analyses of protocols. Where the bases of findings are not reported, they are based on the questionnaire. The findings are organized into four groups: educational goals and priorities over time; teaching profiles; student-teacher interaction; and contribution to the learning process by teachers and external reviewers.

### 4.1 Educational goals and priorities over time

***Overall design objectives***

Across disciplines and sessions, emphasis in reviews was laid on the following topics: design characteristics, design objectives and added value and rationale/explication, in this order. These topics represent inquiry into what the design is, what the design aims to be, and for what reasons. Discussing all three categories during reviews is crucial to effective learning and evaluation. The prominence of 'characteristics' over 'objectives and added value' and 'rationale/explication', indicates an emphasis on the product rather than on the process. This is an accepted standard in sessions with external reviewers, but less so in crits with teachers who are expected to coach students and help them acquire skills and "designerly ways of knowing" and thinking (Cross 2006).

While an overall emphasis of the above topics was similar across disciplines, we nonetheless found differences among disciplines regarding the concerns targeted under each topic. Figure 4.1 proposes a classification comprising five educational objectives, based on consolidated questionnaire entries and similarity of scores within disciplines:

- Needs: Discovery of new needs and/or satisfaction of existing ones.
- Development: Conceptual and/or concrete.
- Priority type I: 'Cool' and fun and/or practical.
- Priority type II: Style (looks) driven, and/or performance driven.
- Emphasis on innovation.

ME provides an example of a bi-polar picture: med-low on needs discovery, tied with med-high on needs satisfaction; low on conceptual emphasis, while high on concrete development; low on aspiring to a 'cool' design, coupled with high on expecting at a practical result; low on style driven design, and high on a performance driven one. Not all disciplines exhibit such polarity, as can be seen in the ID objectives: medium high on needs discovery and need satisfaction; medium-low on conceptual and concrete development[4], medium (high in IDJ, low in IDG) on arriving at a 'cool' design and at a practical one; medium low on style driven and performance driven design[5]. In ARCH, due to the atypical project analyzed, no meaningful observations could be drawn, though we would normally expect a tendency towards higher emphasis on needs discovery, conceptual development, and 'cool' design that

is driven by style. Innovation was medium-high in all disciplines, except ARCH, possibly because architectural education is still 'low-tech' oriented in many institutions.

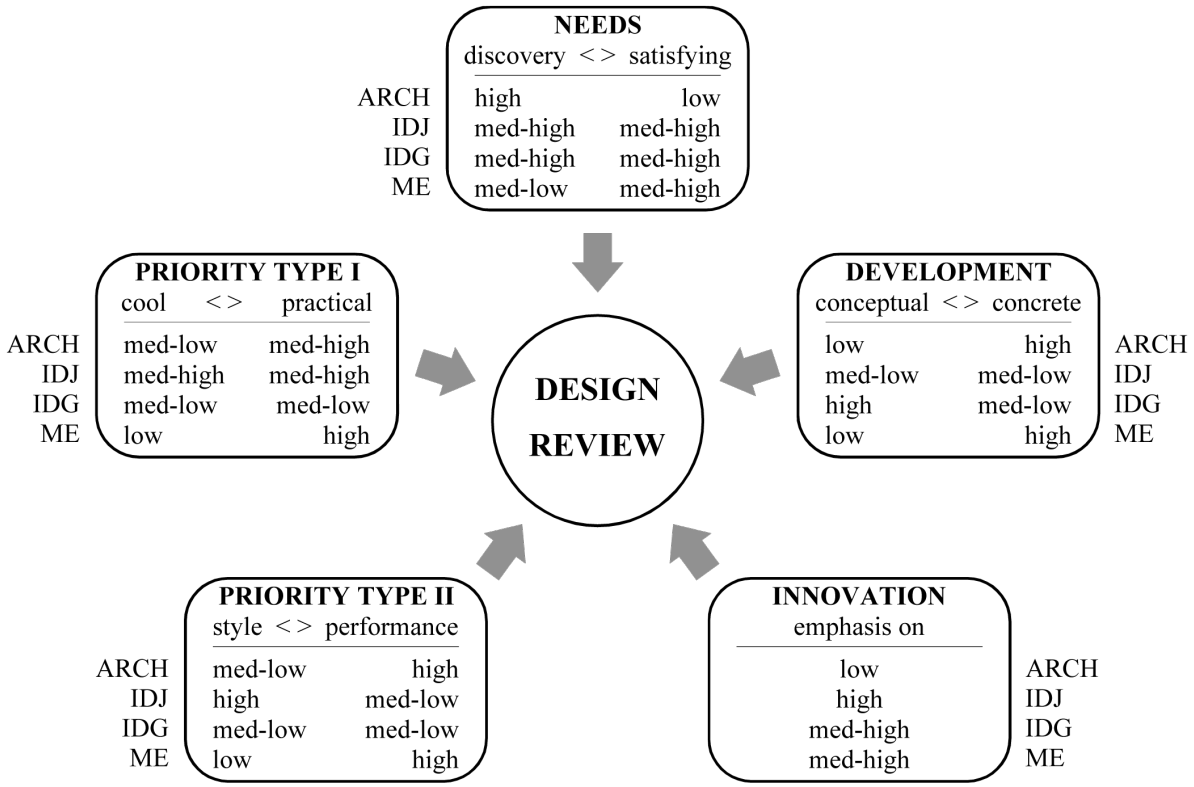


Figure 4.1 Major findings regarding educational objectives in ARCH, IDJ, IDG and ME

Process management is a concern of all design disciplines. While in ME process management was thoroughly investigated, no reference to it was observed in ARCH early on (but extensive reference was detected later in the process), and medium-low reference was observed in ID. Despite the small sample size, we propose that the findings above are typical and variation is due to progression patterns (further elaboration below).

Variances among disciplines were observed regarding 'Design concerns and tools'. While use/function and examples/precedents, appear in ID and ARCH, production and assessment are present in ME. We speculate that a search for functional definitions is more complex in ill-defined problems, typical to ARCH and ID. Conversely, in ME clarification takes place during preliminary analyses, which may explain the lack of discussion later on. Use of examples/precedents, was found in ARCH and ID[6], pointing to a need for further problem clarification, as well as a search for inspiration sources. In ME, assessment substituted for referral to examples/precedents, stressing the need for validation. Extensive discussion about production, takes place in IDJ, less so in IDG and ME. However, ME is highly concerned with feasibility, completeness and costs. Atypically, ARCH also received a high feasibility score, and ID received a medium high score only for functionality, while being low on feasibility, completeness and costs. Representation is not discussed in length in any of the sessions except the IDG crits, where it is highly prominent, assumedly owing to the teacher's personal priorities.

***Progression pattern and change of priorities over time***

Scores of the questionnaire entries: use of alternatives, commitment to initial analysis, and emphasis on schedules and logistics, imply that two approaches exist by which design

transformations take place. We named 'vertical' the first, exemplified by the ME design process, The second, more akin to ID and ARCH, we named 'lateral' (Goel 1995). The vertical process is an aggregation of sub-components that can be developed independently. Hence, the design process is organized as follows: analysis, linear and/or parallel solutions of sub-problems, and assembly. Lateral transformations contradict a linear organization of the design process, since the process is associative and involves a broad, iterative search for possible solutions (from which the most promising is later chosen). In vertical processes, refinement and detailing occur early, within sub-components, and later, towards completion, in lateral processes.

Division of the design in ME into highly independent sub-systems demonstrates a vertical transformation process. A strong commitment to an initial analysis, the need to adhere to strict schedules and the use of a checklist to ensure compliance with objectives, attest to a low tolerance for change of priorities over time. In ARCH and ID, substantial use of alternatives along the preliminary design process reveals a lateral process. Priorities change as the vision becomes clearer; analysis is used, among others, as a source of inspiration rather than as a directive to commit to. Given the nature of the lateral process, it is easier to understand the altering degree of reference to production, functionality, completeness, costs, analysis, and process management in the course of reviews in ARCH and ID, as mentioned earlier under overall design objectives.

***Incorporation of teamwork; team structure***

Teamwork has not been common practice in ARCH, and to some extent, also in ID, a field whose roots are in ARCH. It is only in recent decades that we see teams in architectural practice and education. In the analyzed sessions, we found typical examples of individual work in ID, and a small team in ARCH. The opposite was observed in ME, where all students worked in teams of four to five students, each having his/her own area of expertise and responsibility. It is worth stressing that teams may vary in structure: with/without leader, homogeneous or multidisciplinary, ad-hoc/natural formation, etc. When architects and industrial designers do work in teams, they usually work collectively on all aspects of the design, unlike the common practice in engineering, where individual work on sub-domains prevails.

## 4.2 Teaching profiles

***Teaching models***

We used Quayle's (1985) classification of teaching models, followed by Goldschmidt's (2002) and Goldschmidt et al.'s (2010) consolidation of these models into three profiles: source of expertise/authority, coach/facilitator and 'buddy'. The same profiles have been used by McDonnell (2014), who exemplified them in the critiquing behavior of the IDJ teacher. As mentioned in the literature review, the teacher is expected to act mainly as a coach. As a result, the students learn by getting ongoing feedback about their projects, as well as from demonstrations of design acts by the teacher. Our questionnaire results show that both the ARCH and the IDJ teachers were graded high as coaches. The IDG teacher was graded high for the concept review phase, while for the earlier d-search session he was graded low. The difference between the two sessions is probably because in the d-search phase the teacher mainly listened and asked only clarification questions. We can best understand the difference by looking at the percentage of time the teacher talked in both sessions: while at the concept review he spoke 82% of the time, during the d-search he spoke only 31% of the time (in the remainder of the time the students talked). As for the ME teacher, results regarding coaching are inconclusive: Medium low for the concept design review and medium high for the final design review. When appraising the extent to which the other two teaching models, source of

authority and 'buddy' were detectable in the data, we see that the ME teacher is more of a source of authority, graded very high in this respect. The ARCH and IDJ teachers also achieved relatively high grades as sources of authority, unlike the IDG teacher who scored low. Although none of the teachers that we have studied rated high as 'buddy', it is our impression that the IDG teacher's profile came closest to this definition. His commentary was not restricted to direct matters of the students' designs. For example, he explained to one of the IDG students her erroneous use the term 'conception': "Tell me about conception. What does this have to do with sex?... the word conception is to conceive a child. By adding -tion you made it sex. Okay. Now, there is also conception like to conceive an idea, but you also conceive a child. So, yeah. And then there is contraception, which is the opposite." The student, a newcomer to English, thus received an arguably friendly language lesson, beyond any professional or educational design objective.

***Instructional strategies – Sketches and examples***

The literature indicates two different approaches regarding the relationship between knowledge and skills in the studio. On the one hand, the studio is where knowledge should be conveyed (Oh et al. 2012, Cennamo et al. 2011); on the other hand, the preference for mastering skills, assuming that nowadays knowledge can be accumulated easily without the teacher as provider. This raises the question: what is the teacher's role in the studio? Our investigation shows that the ARCH and ID teachers' approach is similar, but it differs from the ME teacher's approach. The ARCH, IDJ and IDG teachers chose (consciously or unconsciously) to convey knowledge in the studio, talking about precedents and other examples to clarify ideas (e.g., Japanese garden and stoa in ARCH, Ross Lovegrove's chair in IDG, etc.). The ME teacher did not mention references at all; instead, he used a checklist that examined the students' mastery of different skills, such as completeness, functionality and assembly. This shows that as a teacher he emphasized technical proficiencies, and that students were expected to look for additional knowledge by themselves as a part of their education.

We also asked how often the teacher used sketches to illustrate his views (a sketch also includes various notations and written words). Designers place great emphasis on sketching because it is often thought to be associated with innovation and creativity (Purcell & Gero 1998). From concept design ideas through highly detailed representations, the sketch is also an important activity of communication (Rodgers et al. 2000). Nevertheless, except for the ARCH teachers, who were graded medium-high regarding sketching, all other teachers hardly used sketches during the crit.

***Teacher's involvement in selecting/proposing concepts***

As already discussed, coaching in the studio involves proposing possible responses or design acts to the students. Involvement in the project differs from one teacher to another and may change in respect to a specific project or a student. The teacher may spot difficulties in the process that can be resolved by suggesting specific actions and normally he or she does not refrain from making such suggestions. Sometimes a teacher's personal interest in a specific project influences his or her degree of involvement. For example, the IDG teacher's special interest in a student's 'bicycle as washing machine' project leads him to offer: "Do you have a bicycle? I mean I have some bicycles you can borrow. Do you know how to ride a bicycle?"

Regarding the teachers' contribution of ideas/solutions to the students' project, both IDJ and ARCH teachers scored high. The IDJ teacher contributed various possible solutions to the students; for example, he offered advice on choosing materials possibilities when discussing one of the projects, and helped another student choose the most appropriate option from amongst different alternatives because it was "solid, nice and simple." Unlike them, the ME

and IDG teachers were graded medium-low in this respect. Although the latter lent a student a bicycle for him to try out his design ideas, he avoided giving him specific directives, and in all cases, the students in his studio decided themselves on the concepts to be developed. Similarly, when looking at teachers' participation in choosing ideas, results showed the same trend: the IDJ teacher was graded high, while the IDG and ME teachers scored low. In ARCH, the score was low early in the process, and subsequently changed to high. Section 4.3 further elaborates on this topic. Figure 4.2 summarizes our findings regarding the various aspects of teaching models in ARCH, IDJ, IDG and ME.

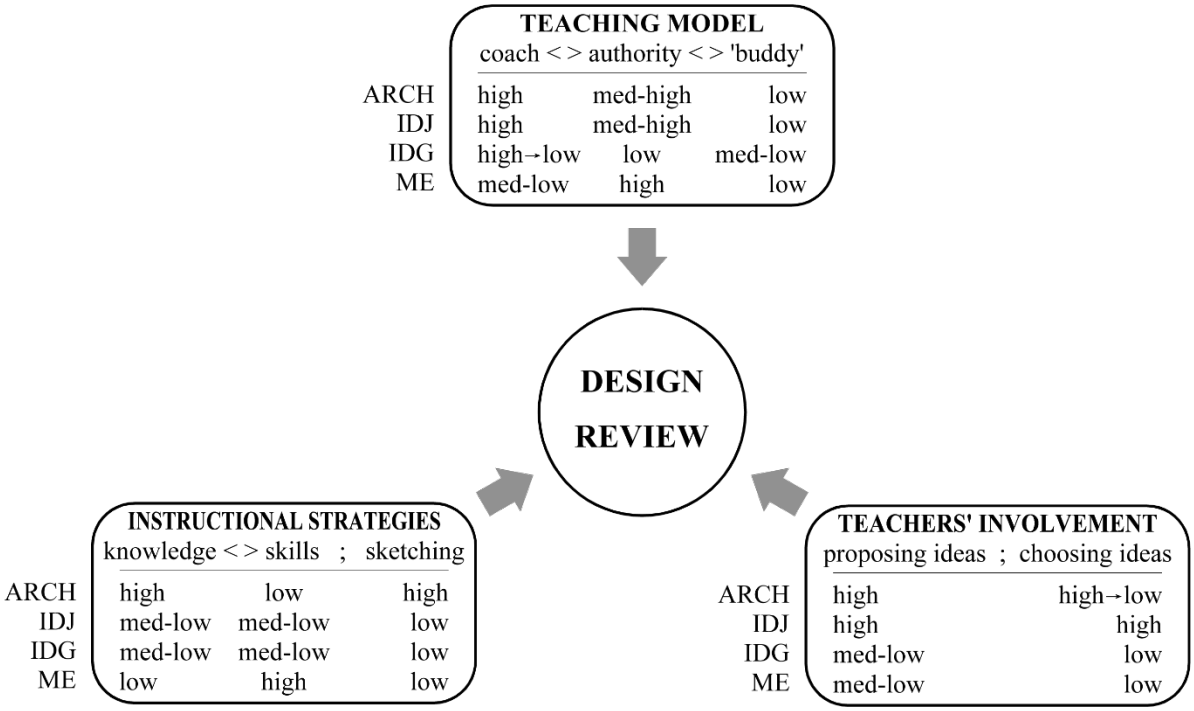


Figure 4.2 Major findings regarding teaching profiles in ARCH, IDJ, IDG and ME

## 4.3 Student-teacher interaction

***Design studio crit structure***

One of the research objectives was to understand the typical structure of a review session in each field, focusing on the teacher-student dialogue (Uluoğlu 2000, Schön 1987). The typical structure of the architectural has students presenting their design, and the teacher asking questions, commenting and offering critical remarks on various aspects of the work. As noted in section 4.2, teachers also use examples such as architectural precedents and references to illustrate design principles and enrich the students' inventory of solutions. Occasionally, teachers sketch to help visualize possible design solutions. Alternative solutions may also be considered. Students typically participate actively throughout the crit, expressing their own views. Given the teachers' expertise, often the dialogue is not balanced and the teachers elicit more issues in a larger number of categories (Ferreira et al., 2014; Goldschmidt et al., 2010).

In an early IDJ session, students presented five alternative solutions and the teacher discussed their strengths and weaknesses with them. The teacher critiqued and compared among the different design options, suggested possible directions to follow, helped make design decisions and select the most promising ones; for example, he said to a student "This – let's work on this because this is a great concept".

During the d-search session, IDG students presented the preliminary research they carried out to understand and define the design problem. The teacher asked clarification questions

and remarked primarily on technical and graphic issues related to the presentations; later the discussion focused on the design problem, rather than on potential solution ideas. In the concept review session, the same teacher had little to say about the development of the designed artifacts; he commented mainly on the graphics of the presentation, for example: "You might look at resetting the kerning because your – the letters are hitting each other and they should have little spaces between them." Alternative ideas were generally not reviewed and students mainly listened to the teacher.

In ME, students, who work in teams, presented one after the other aspects of the project that they were responsible for. Their detailed and extensive technical descriptions were accompanied by PowerPoint slides, their goal being to receive the teacher's confirmation. Their explanations were intercepted by short interventions by the teacher, who asked clarification questions, followed by analyses and suggestions. The objective of his interventions was to ensure design completeness in terms of full assembly and operability. This is illustrated in his words: "All right, so you have it fully assembled, minus the issues that you talked about that give us like a B. And it's, ah, not fully functional."

In order to gain further insight into the teacher-student interactions, we calculated the percentage of each party's speaking time in the various sessions. Differences were found between ME and the rest of the disciplines. In ME the teacher talked about 16% of the time in each session, rated low compared to ARCH (62% in single teacher session, 74% in session with two teachers), IDJ (75%), and IDG (31% in the d-search and 82% in the concept review). This suggests that in ARCH and ID (with the exception of the d-search session), the teacher dominated the crit, in contradiction to the spirit of democratizing the studio and doing away with the teacher's hegemony (Hsiao & Cheng 2006). In contrast, in ME, students present and explain their projects extensively and the teacher intervenes only from time to time. In no case can we talk about a fruitful dialogue during the crit. This raises questions regarding the nature of design learning in the studio setting in light of educational objectives, as discussed earlier in section 4.1.

***Student participation in reviews***

We checked whether teachers encouraged students' participation in reviews of peers' work. Active participation of peers is considered a learning opportunity, which fosters critical thinking and communication skills. We found that in most cases reviews were individual (or with a team in the case of ME and ARCH); only the IDG teacher held group reviews in which he explicitly asked students to critique their peers' work, but the attempt failed. Peers participation in reviews was graded low or medium low in IDG; in all the other disciplines, it was uniformly low. Voluntary participation at students' own initiative was also low across disciplines, except in IDG where it was medium-low, despite the fact that many of the IDG students had a poor command of English, which was a predicament. Most teachers did not try to promote students' participation in the review of peers, which may attest to a lack of awareness of the potential learning benefits that participation holds. The issue of peer critiquing is discussed extensively in Oak and Lloyd (2014).

***Extended final reviews***

We were interested in looking at final studio reviews and asked whether they were used to develop an extended 'meta' discussion that touches on major issues, beyond the immediate scope of the task, as recommended by Cennamo et al (2011). In final reviews in IDJ, IDG and ME students presented their designs to a 'jury' (Anthony 1991) composed of the teacher and external reviewers; in the ID studios these were clients. A large part of the discussion focused on functional, construction, production, and marketing aspects related to the product, and somewhat to conceptual issues. In ME, safety and cost issues were also discussed. In no case

was there an attempt to initiate a wider debate on critical concerns that go beyond the design outcome itself, and the final reviews were not too different from previous reviews. This is unfortunate as it probably precluded an opportunity for double-loop learning (Argyris & Schön 1974). The ME teacher stood out in that he held a concluding session after the final review. In that session he asked students what they had learned and discussed with them the importance of schedules and complete performance deliverables in the industry: "But in industry, this would not be acceptable… if it [schedule violation] happened a second time, for sure, you'd be fired. Because I have to have a technical performance, and I have to have it within a – within the schedule."

Data from the final ARCH review was not available to us. However, the design studio culture in architecture calls for discussions of critical issues commonly shared by several projects, with the participation of external reviewers, teachers and students. In the studio we have observed, we believe that clients participated in the final review as well. Figure 4.3 summarizes our findings regarding student-teacher interaction in ARCH, IDJ, IDG and ME.

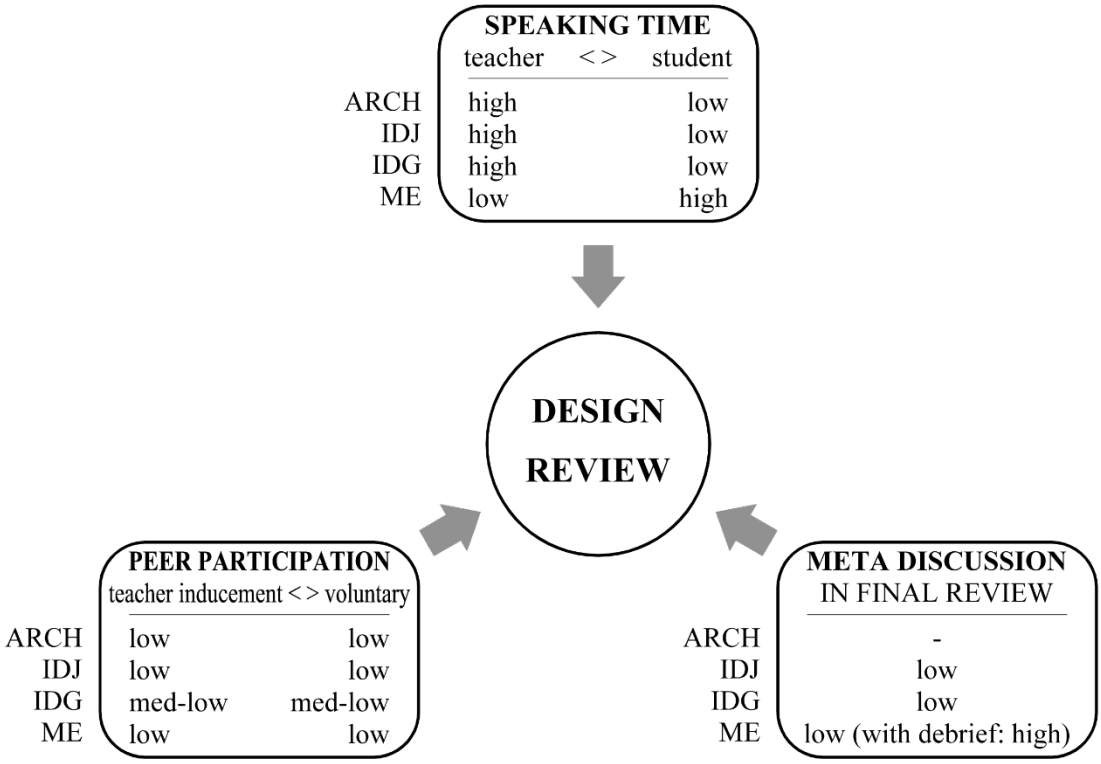


Figure 4.3 Major findings regarding student-teacher interaction in ARCH, IDJ, IDG and ME

### 4.4 Contribution to the learning process by teachers and external reviewers

With the aim of preparing students for real-life, design educators often bring practice into the studio in the form of practitioners who participate in final reviews and clients who sponsor projects and participate in various reviews.

As is often the case, the studios we have analyzed involve external reviewers. In the ME studio, the final review is conducted with a large number of visiting reviewers – all experienced practitioners. In the other studios, real clients contribute the project topics – seating in IDJ, products associated with home laundry in IDG, and structures for a public open space made of bamboo in the ARCH studio[7]. We assume that beyond the value derived from working on a real-world problem (Cennamo et al. 2011), the students also benefit from impartial feedback that helps socialize them into the profession (Brandt et al. 2013). A formal

presentation to external reviewers is also an opportunity to hone students' communication skills (e.g., Besterfield-Scarce et al. 2000). Our analyses pertain to the contribution of clients and practitioners as compared to the studio teacher.

***Roles of teacher, client and external reviewer***

Teachers guide the design process and help students move from one phase to another. External reviewers from practice usually participate in the final review, as in the ME studio; they are not familiar with the students' processes and their comments refer exclusively to the product. Clients are more involved in the process and in both ID studios, they offer comments at the end, and in an interim review in which they advise students as to which proposals are best suited for further development. Clients and professionals are experts and sources of authority; they do not coach students, but perform the role of professional socialization. As we learned in section 4.2, teachers also come through as experts and sources of authority but they act mainly as coaches, to a medium-high to high degree. Coaching focuses on the design process and acquisition of skills (e.g., Utaberta 2011). This is particularly evident in a post hoc session in ME, in which the teacher tells students what is important in industry and what may fail them.

There are some interesting disciplinary differences in the roles of teachers and external reviewers. In ME, where students learn by themselves (in teams) and seek the teacher's confirmation, the external reviewers interrogate the students to ensure all aspects of their design have reached the benchmark. A checklist exists, explicitly or implicitly. The issues under scrutiny relate to function and performance, production or assembly, completeness, costs, and schedules. Emotional issues, styling and the quality of the visual presentation receive little attention, from both teacher and external reviewers. Innovation is of no concern to the external reviewers, while the teacher encourages it to a fairly high degree. How exciting or "cool" the product is, is of no concern to anyone. In contrast, in both ID studios, the teachers stress the fun and excitement aspect of the product, and the clients too are interested in "cool" designs. For example, the IDG teacher says to a student "… don't be afraid to let yourself go wild and crazy in your ideations"; the IDJ teacher approves of a sketch: "Excellent. That's fun", and says to another student: "that's what the personality of the chair needs to be, fun." A client says to a student "I think this is pretty cool." Innovation is appreciated in the sense that products are sought that are new to the market. Functional issues are of relative importance to clients, and somewhat less so to teachers. Production and assembly receive medium attention at a late stage of the project; completeness, costs and schedules are not discussed. The IDJ teacher touches on emotional issues, the IDG teachers and clients almost ignore this issue. Styling is high on the list of IDJ teacher and clients; it is of surprising little concern to the IDG teacher – somewhat more so to the clients. A good visual presentation is important to all ID reviewers, and especially to the IDG teacher who goes into painful details in his crits. All parties shy away from making negative comments; the ID reviewers offer encouraging comments, whereas the ME teacher does not see this as his role.

In ARCH, we cannot compare the teachers to other reviewers. We can confirm that like the other teachers, they perform as experts and coaches alike, they do not make negative comments and positive comments are scarce at first, but then more frequent; they participate in choosing the most promising ideas, as does the IDJ teacher, but not the IDG and ME teachers. The quality of visual presentation does not play a role, maybe because it is very early in the design process. Creativity and innovation are not explicitly addressed. Figure 4.4 summarizes our findings regarding contribution and roles of teachers and external reviewers to the learning process in ARCH, IDJ, IDG and ME.

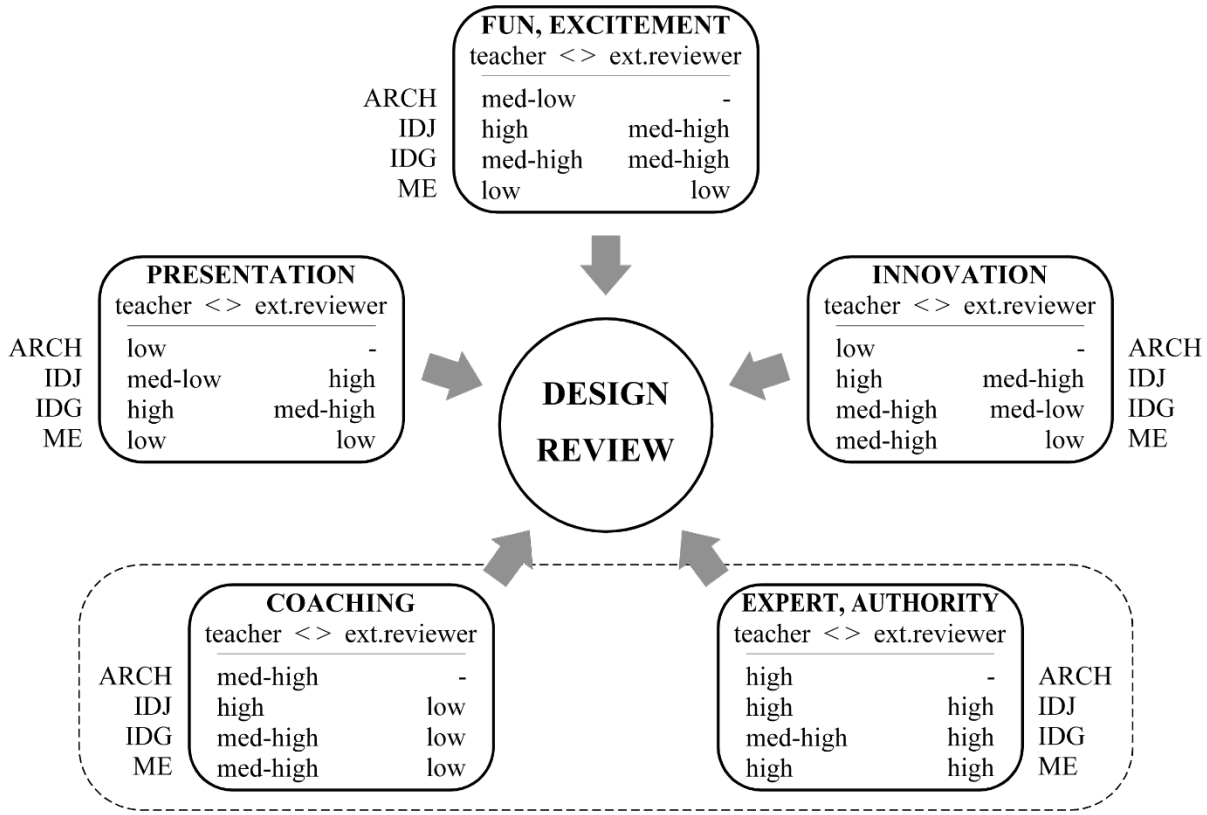


Figure 4.4 Major findings regarding contribution to learning process by teachers and external reviewers in ARCH, IDJ, IDG and ME.

***The teacher as client surrogate***

Teachers want their students to succeed, for both the students' and their own sake. The students do not have sufficient experience to foresee the client's preferences; therefore, whether or not clients are actually involved in the process, teachers often assume the role of surrogate client, in order to model the client's reactions[8]. In the ARCH sessions, we do not encounter examples of this attitude. The IDG teacher says to a student "And I think it's the kind of thing that they [client] would love…" The ME teacher explains in a 'debriefing' that he acted like a client (establishing the schedule) in order to prepare students for real-life. The IDJ teacher helps students choose ideas that would impress the clients: "Ah, so they're [clients] looking for you to do something really exciting"; and in another review: "Ah, I think that the material they're [clients] looking for…" The IDG teacher does not interfere in students' choices and as mentioned above, only pushes them to be "wild" as he believes this is what the clients expect.

## 5. Conclusions – contribution to design education

In this section, we first map our principal empirical findings for each of the three design disciplines, based on the questionnaire together with qualitative analyses of the protocols, onto the topics extracted from the literature review. By doing so, we answer the research questions posed in section 2. Table 5.1 is a summary of this comparison. We conclude by pointing to some limitations of this study, followed by a set of general recommendations for design education.

A rough overview of the findings points to more profound differences between mechanical engineering reviews and all other reviews, in industrial design and architecture.

There were dissimilarities between the junior and graduate industrial design reviews, which we attribute mainly to individual differences between the two teachers in question (and possibly the phase of training). For the conclusions, we bundle them together. Although architecture and industrial design have quite a lot in common, we nevertheless noted some differences between them. Obviously, the fact that we have only one or two teachers in each discipline limits the generality of the conclusions, but we focus on those findings that we take to be representative of the state of the art.

### 5.1 Studio learning objectives

Three major issues stand out when examining the learning objectives as revealed in design reviews. The first is the dichotomy between skill and knowledge acquisition in the studio. In ID and ARCH reviews, teachers impart knowledge as well as guide the design development and discuss with students how to achieve their goals. In ME, the teacher checks whether relevant knowledge has been used in developing the design, but he does not communicate knowledge in the studio (Q.1: Skill building and knowledge transfer). What design critiquing is driven by, is the second issue. The crit in ME is clearly performance driven, with a focus on need satisfaction. Needs must be completely specified in advance and are binding. The design progresses through combining solutions to well-defined sub-problems. Designing in the ID studios is innovation driven and so is the review; the focus is on discovering new needs to which the designed product caters. In ARCH, creativity drives the design process in the studio. In these disciplines, emotional appeal is high on the list (Q.2: Performance vs. fun; see below). Needs are rarely new, but new ways of addressing them are sought. In both cases, the design process is iterative and all of its aspects require one well-integrated solution. The third issue is derived from the second, namely what are the expectations from the final deliverables. In ME a fully functional prototype is anticipated. In ID a full-scale prototype is expected but it need not be functional, at least not fully. In ARCH, the outcome is expected to be modeled in simulations, mostly in the form of drawings but also as 3D scale models. Often these representations are rather conceptual in nature and they are not expected to address every aspect of the designed building or urban scheme.

### 5.2 Pedagogical strategies

Under the heading of pedagogical strategies, we find five issues that define the studio review scene. The first is the reviewer's profile. As to the external reviewers, clients and practitioners alike, they all act as experts and authorities. They evaluate the students' designs in terms of their potential success in the market. The studio teachers act mostly as coaches, but they also act as experts, to various degrees (Q.3: Teaching profiles). The nature of the coaching activity is the second issue under consideration. In ME this meant confirmation, that is, making sure the design satisfies requirements at each stage, and a post hoc discussion with students about what they have learned, and what they must pay special attention to in industry (mainly meeting schedules) (Q.4: Meta discussions). In both ID and ARCH, the teachers are more directly involved in the development of projects: they assess alternatives, assist in choosing the ones to be pursued further, and provide advice regarding their development. They also point to examples, especially relevant precedents. In ARCH, the teachers also demonstrate design acts by sketching during the crit (Q.5: Teacher's involvement in project). Assessment of projects is open-ended; teachers and external reviewers choose what to focus on in their comments. In ME, assessment is strictly by a checklist, aimed at ensuring full coverage of all issues regarding the performance of the designed entity. Two more issues are relevant under the strategies heading. One issue relates to the students' mode of work: as individuals or teams. In ME, students work exclusively in teams (four to five students); within the team students work individually – each of them is assigned a different task, often representing a

separate discipline or sub-discipline. In ID, only the initial research phase was carried out in teams of two; for the rest, the work was individual. In ARCH, three students worked collaboratively, without role differentiation. Work in teams is still not the norm in architecture and when it takes place, no specialized roles are established. Lastly, the nature of the project is under scrutiny: is it a realistic project or a more abstract exercise. In our samples, all projects were realistic, with teachers serving as surrogate clients, in addition to real clients that were involved as external reviewers in ID and ARCH (but the ARCH records are not available). Generally, theoretical design projects are quite prevalent in architectural education.

### 5.3 Crit and review contents and purpose

Two main concerns pertain to the contents and purpose of the design review, and especially the personal crit. The first is the dichotomy between focus on design process and design product. The final result is always a product of some kind, following a process that brings it into being. In ME, the focus is on the product. In ID and ARCH, the opposite is true: in most cases the process comes first, and the product is almost an interim result of the process for the point in time at which the review takes place. There is a lot of talk about the potential of the presented design, even if it is yet unrealized. No such talk is heard in engineering reviews (Q.6: Focus on process vs. product). The second issue has to do with the review and crit confines: are they restricted to the project at hand, or are there, in the course of development, and especially at the end, also meta-discussions that augment learning benefits by raising general questions related to design. The ME teacher does conduct a conversation after the final review, in which he talks mainly about what students must be aware of in terms of fulfilling their duties in industry. In ID, no meta-discussion takes place; in ARCH, we have no records but typically, such discussions are prevalent in architectural studios (Q.4: Meta discussions).

Finally and most importantly, there is one issue that cuts across all three headings, which we may call “added value” to the quality of the final result, and how it is achieved. Whereas success criteria in ME rest entirely on performance, in ID a product is expected to be exciting. To quote the IDJ teacher: “But it needs to be, it, it, it has a great opportunity to be fun.” There is no precise definition of “exciting” but the terms “fun”, “cool” and the like are used in this context. The IDJ teacher uses ‘fun’ 28 times in two preliminary crit sessions, and the IDJ clients use it 14 times in two reviews. A fun product is one that does more than function well – it appeals to the user’s emotions; the user loves it for qualities beyond its performance. Performance criteria may be relaxed if this helps achieve a fun product. The equivalent in architecture is related to style; the way a building looks, but also users’ experience inside the building and how much ‘fun’ it is, for example, as a result of views from one space to another, a dramatic impact of a space, and so on. An exciting building is an utmost goal, even at the expense of functional performance. Tradeoffs are acceptable, that is, poor fulfillment of certain design requirements may be excused if something ‘more exciting’ is provided instead (Q.2: Performance vs. fun). There are many examples in the history of industrial design and architecture for the precedence of fun and style over performance. For example, Philippe Starck’s lemon squeezer has become an iconic product despite its poor performance in extracting juice from lemons. The Sydney Opera house has become a symbol of the city despite severe performance failures, e.g., a significant portion of the stage is not visible from many seats.

Table 5.1 Comparison among disciplines – mapping of empirical findings onto literature categories

| | | ME | ID | ARCH |
|---|---|---|---|---|
| Learning objectives | | Skills acquisition (knowledge to be acquired alone) | Skills + knowledge | Skills + knowledge |
| | | Performance driven; Focus on need satisfaction | Innovation driven; Focus on need discovery | Creativity driven; Focus on need satisfaction in new ways |
| | | Full functionality requirements (functioning prototype) | Prototype level functionality requirements (partially conceptual) | Graphic simulation level requirements (largely conceptual) |
| Pedagogical strategies | | Teacher profile: Expert/Authority, Coach; External reviewers: Experts/Authorities | Teacher profile: Coach, expert[1]; External reviewers: Experts/Authorities | Teacher profile: Coach, expert; External reviewers: Data not available[1] |
| | | Coaching: socialization into profession (practice) | Coaching: assistance in sorting alternatives, examples/precedents; Socialization into professional practice | Coaching: assistance in sorting alternatives; examples/precedents; Demonstrating (sketching) |
| | | Checklist assessment | Open-ended assessment | Open-ended assessment |
| | | Work in teams with heterogeneous disciplinary roles | Individual work[1] | Individual work or small teams with homogeneous disciplinary roles |
| | | Realistic project with teacher as surrogate client | Realistic project with real clients | Realistic project with real clients[1] |
| Crit & review contents & Purpose | | Focus on product, then process | Focus on process, then product | Focus on process, then product |
| | | Meta discussion mainly focuses on lessons related to future professional practice | No meta discussion | Norm: Meta discussion to augment learning opportunities |
| Added value | Learning objectives/Pedagogical strategies/Review contents & purpose | Rigid performance criteria; Performance centered | Relaxed performance criteria; Exciting product centered | Tradeoffs; Exciting style centered |

[1] In some respects the available data is not typical of design education. In industrial design, teachers are usually coaches (whereas the IDG teacher gets a low coaching score) and students often work in small teams. In architecture, projects with real clients are rare (unlike this case) and external reviewers are experts/authorities.

The overarching difference between engineering and other design disciplines in this respect is as true of education as it is of practice. We find that the entire review culture in design studios is highlighted by this variance, and therefore we chose to incorporate it into the title of this study.

Before we briefly list *recommendations* that we inferred from the study, we should acknowledge three major limitations of the current work, which we hope to overcome in future research. The first regards the sample. The dataset we analyzed consists of a small number of review sessions (those we considered comparable); only one or two teachers in each discipline conduct crits, and the socio-cultural background of the settings is not sufficiently global. Second, the authors being architects, we felt it was indispensable to

include this design discipline in the study. We have therefore added audio records of two design sessions from a different setting, which we believe are comparable to the sessions in the common dataset. However, in architecture, we do not have records of sessions at an advanced phase of the project, especially with clients; the protocols are in a different language (Hebrew) and therefore cannot be globally shared. Last, the timetable obliged us to work on several aspects of the study in parallel, notably the literature review and the preparation of the questionnaire. Therefore, there are some mismatches between the two, which complicated the study.

The following recommendations are built on strengths found in one or another design review culture, which we believe other disciplines would do well to adopt.

1 Function and fun are not contradictions. Both are desirable in design outcomes and reviewers of all types should encourage a synergy between them.
2 Crits should focus on both skill and knowledge acquisition.
3 One or another kind of checklist containing criteria for the assessment of design outcomes is relevant to all design disciplines.
4 Meta-discussions regarding broad design issues can augment deep learning opportunities in all design disciplines.
5 Students (peers) should be involved in critiquing and reviewing in all design studio settings.
6 External reviewers of various kinds are essential in all disciplines.
7 The discussion of examples and precedents helps build an inventory of cases, thus advances expertise.
8 In all design disciplines, there is a need to cover the spectrum from preliminary scheme to realization (production, manufacturing, assembly, construction) and more generally, the entire life cycle of the product.
9 Process management should be emphasized in all studio settings.
10 There is an acute need for a comprehensive theory of design pedagogy that would also lead to training programs for design teachers.

## Notes

[1] The shared Purdue database did not include data from architectural design studios. Since it was essential for us to include architecture in this comparison, we added data collected elsewhere (see section 3 – research methods).

[2] We have chosen to use the term ‘teacher’ to denote a faculty member assigned to lead and supervise the studio. Other terms found in the literature, which we take to be equivalent to ‘teacher’, are instructor, tutor, studio master, and in French: patron (boss). The term ‘coach’ has also been in increasing usage in this context.

[3] The architecture studio task was the design of structures for an open urban space. The students determined the nature of the structures, but they had to be made of bamboo. The local city council acted as a client for the project. Our data includes only the two sessions we have analyzed. The protocols were recorded and transcribed by Sharon Weiser, as part of a graduate course assignment.

[4] In IDG, a different pattern – high on conceptual, low on concrete: possibly due to the nature of the task.

[5] In IDJ, a different pattern – high on looks, low on performance: possibly due to the course level (juniors).

[6] Differences in the nature of IDJ and IDG tasks caused variations in the frequency of pointing to references.

[7] As already noted, we do not have a documentation of the final review with clients in the ARCH studio.

[8] The syllabus of CMU's architecture studio on Occupancy (48-505) focuses on "in-depth study of client needs … with a real or surrogate client…" http://www.cmu.edu/architecture/programs/courses/design-studio-courses.html

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# Appendix: Questionnaire and mean scores

Note: The order of questions within each category is intentionally random

| | | Architecture | | Industrial Design - Junior | | |
|---|---|---|---|---|---|---|
| **SESSION** | | Session 1 | Session 2 | Second review | Client review | Final review |
| **SESSION INFORMATION** | | | | | | |
| 1 | Project phase | early | advance | early | advanced | advanced |
| 2 | Project type | team | team | individual | individual | individual |
| 3 | Review format | 1-on-1 | round table | 1-on-1 | 1-on-1 | facing class |
| 4 | Reviewer(s) identity | teacher | teacher | teacher | client | jury |
| 5 | Session duration | N/A | N/A | 14:37 | 06:05 | 07:02 |
| 6 | Percentage of reviewer(s) speaking time | 62% | 74% | 75% | 29% | 27% |
| **A – REVIEWING MODEL** | | | | | | |
| A1 | The reviewer(s) encourage(s) students' participation in the review of peers' work | 1.0 | N/A | 1.0 | 1.0 | 1.0 |
| A2 | The reviewer(s) contribute(s) ideas/solutions to the students' projects | 4.0 | 5.0 | 4.4 | 2.7 | 3.5 |
| A3 | The reviewer(s) use(s) examples from existing work or other domains to clarify his views | 4.0 | 4.0 | 1.5 | 1.0 | 1.0 |
| A4 | The reviewer(s) sketch(es) to illustrate his views (incl. various notation and written words) | 4.0 | 4.0 | 1.5 | 1.0 | 1.0 |
| A5 | The reviewer(s) make(s) positive (encouraging, approving, appreciative) comments | 1.0 | 4.0 | 4.5 | 2.8 | 3.2 |
| A6 | The reviewer(s) make(s) negative (rejecting, dismissive, unappreciative) comments | 1.0 | 1.0 | 1.0 | 1.2 | 1.2 |
| A7 | The reviewer(s) participate(s) in choosing ideas | 1.0 | 4.0 | 4.9 | 1.5 | N/A |
| **B – TASK CONSTRUAL** | | | | | | |
| B1 | The task requires (existing) need satisfaction | 1.0 | 1.0 | 4.4 | 4.0 | 3.3 |
| B2 | The task requires the discovery of new needs | 5.0 | 5.0 | 4.1 | 4.3 | 4.7 |
| B3 | The expected design outcome is at a conceptual level | 1.0 | 1.0 | 2.9 | 3.2 | 3.5 |
| B4 | The expected design outcome is at a concrete level | 5.0 | 5.0 | 3.2 | 2.5 | 2.5 |
| B5 | There is an emphasis on achieving a "cool" "fun" exciting product that caters to emotions | 2.0 | 2.0 | 4.7 | 3.0 | 3.8 |
| B6 | There is an emphasis on innovation | 1.0 | 1.0 | 3.7 | 3.0 | 4.3 |
| B7 | There is an emphasis on arriving at a feasible, functional, complete and efficient product, which is cost-effective | 5.0 | 5.0 | 1.8 | 1.7 | 2.0 |
| B8 | There is an emphasis on producing a good presentation | 1.0 | 2.0 | 2.4 | 1.0 | 1.7 |
| **C – DESIGN PROCESS AND EVALUATION** | | | | | | |
| C1 | Alternative ideas/solutions are requested/considered | 4.0 | 3.0 | 5.0 | 4.3 | N/A |
| C2 | A commitment to the initial analysis is expressed | 1.0 | 2.0 | 1.0 | 4.0 | 4.5 |
| C3 | The review focuses on functional issues | 1.0 | 4.0 | 3.6 | 4.2 | 4.8 |
| C4 | The review focuses on production/ assembly/ construction issues of designed entity | 1.0 | 4.0 | 2.3 | 1.3 | 3.8 |
| C5 | The review is carried out with a checklist | 1.0 | 1.0 | 1.2 | 1.0 | 1.0 |
| C6 | The review emphasizes styling (looks) | 3.0 | 3.0 | 4.9 | 4.5 | 3.8 |
| C7 | The review emphasizes completeness | 2.0 | 4.0 | 1.2 | 1.0 | 1.0 |
| C8 | The review refers to costs | 1.0 | 3.0 | 1.0 | 1.0 | 1.2 |
| C9 | The review emphasizes emotional issues associated with the product | 1.0 | 1.0 | 3.8 | 2.8 | 1.5 |
| C10 | The review emphasizes schedules and logistics | 2.0 | 4.0 | 3.7 | 1.0 | 1.0 |

**D – STUDIO AMBIANCE**

| | | | | | | |
|---|---|---|---|---|---|---|
| D1 | The ambiance during the review is formal/professional/task oriented | 4.0 | 4.0 | 4.4 | 3.7 | 4.3 |
| D2 | The ambiance during the review is 'social' – encourages informal interaction | 3.0 | 2.0 | 1.6 | 2.2 | 2.5 |
| D3 | The reviewer(s) act(s) as an expert/source of authority | 4.0 | 3.0 | 4.1 | 4.0 | 4.5 |
| D4 | The reviewer(s) act(s) as a supporting "buddy" | 1.0 | 1.0 | 1.3 | 1.2 | 1.2 |
| D5 | The reviewer(s) act(s) as a coach/facilitator | 4.0 | 5.0 | 4.7 | 1.3 | 1.0 |
| D6 | Peers participate in reviews | N/A | N/A | 1.0 | 1.0 | 1.0 |

| | **Industrial Design - Graduate** | | | **Mechanical Engineering** | | |
|---|---|---|---|---|---|---|
| **SESSION** | D-search | Concept review | Client review | Concept des. rev. | Final des. rev. | Final debrief |

**SESSION INFORMATION**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Project phase | early | early | advance | advance | advance | post-hoc |
| 2 | Project type | team | individu | individu | team | team | team |
| 3 | Review format | round table | 1-on-1 | online | facing class | 1-on-1 | facing class |
| 4 | Reviewer(s) identity | teacher | teacher | client | teacher | teacher | teacher |
| 5 | Session duration | 25:17 | 16:02 | 12:54 | 30:59 | 19:56 | 14:43 |
| 6 | Percentage of reviewer(s) speaking time | 31% | 82% | 32% | 16% | 17% | 75% |

**A – REVIEWING MODEL**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A1 | The reviewer(s) encourage(s) students' participation in the review of peers' work | 2.0 | 2.9 | N/A | 1.0 | 1.0 | 5.0 |
| A2 | The reviewer(s) contribute(s) ideas/solutions to the students' projects | 1.0 | 2.6 | 2.3 | 2.3 | 1.0 | N/A |
| A3 | The reviewer(s) use(s) examples from existing work or other domains to clarify his | 1.0 | 1.5 | 1.0 | 1.3 | 1.0 | N/A |
| A4 | The reviewer(s) sketch(es) to illustrate his views (incl. various notation and written | 1.0 | 2.3 | N/A | 1.0 | 1.0 | N/A |
| A5 | The reviewer(s) make(s) positive (encouraging, approving, appreciative) | 3.0 | 2.9 | 3.3 | 2.8 | 4.3 | N/A |
| A6 | The reviewer(s) make(s) negative (rejecting, dismissive, unappreciative) comments | 1.0 | 1.3 | 2.0 | 1.8 | 1.0 | N/A |
| A7 | The reviewer(s) participate(s) in choosing ideas | 1.0 | 3.0 | 4.3 | 1.0 | 1.0 | N/A |

**B – TASK CONSTRUAL**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| B1 | The task requires (existing) need satisfaction | 4.5 | 3.3 | 2.3 | 3.8 | 3.8 | N/A |
| B2 | The task requires the discovery of new needs | 3.0 | 4.5 | 3.0 | 2.8 | 2.8 | N/A |
| B3 | The expected design outcome is at a conceptual level | 5.0 | 4.3 | 5.0 | 1.0 | 1.0 | 1.0 |
| B4 | The expected design outcome is at a concrete level | 1.0 | 2.2 | 2.3 | 5.0 | 5.0 | 5.0 |
| B5 | There is an emphasis on achieving a "cool" "fun" exciting product that caters to emotions | 3.0 | 3.6 | 3.0 | 1.5 | 2.3 | 1.0 |
| B6 | There is an emphasis on innovation | 3.0 | 3.3 | 2.3 | 3.3 | 3.3 | 1.0 |
| B7 | There is an emphasis on arriving at a feasible, functional, complete and efficient product, which is cost-effective | 1.5 | 2.8 | 2.0 | 5.0 | 5.0 | 5.0 |
| B8 | There is an emphasis on producing a good presentation | 2.5 | 4.9 | 2.0 | 1.3 | 1.3 | 1.0 |

**C – DESIGN PROCESS AND EVALUATION**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| C1 | Alternative ideas/solutions are requested/considered | 3.0 | 2.3 | 5.0 | 1.5 | 1.0 | N/A |
| C2 | A commitment to the initial analysis is expressed | 4.0 | 2.5 | 5.0 | 5.0 | 5.0 | 5.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| C3 | The review focuses on functional issues | 2.5 | 3.3 | 3.3 | 5.0 | 5.0 | 5.0 |
| C4 | The review focuses on production/ assembly/ construction issues of designed entity | 1.0 | 2.0 | 1.3 | 5.0 | 5.0 | 5.0 |
| C5 | The review is carried out with a checklist | 1.0 | 1.0 | 1.0 | 4.5 | 5.0 | N/A |
| C6 | The review emphasizes styling (looks) | 1.0 | 2.8 | 2.7 | 1.8 | 1.0 | 1.0 |
| C7 | The review emphasizes completeness | 1.0 | 1.4 | 1.7 | 5.0 | 5.0 | 5.0 |
| C8 | The review refers to costs | 1.0 | 1.0 | 1.0 | 5.0 | 1.0 | 5.0 |
| C9 | The review emphasizes emotional issues associated with the product | 1.5 | 1.1 | 1.7 | 1.0 | 1.8 | 1.0 |
| C10 | The review emphasizes schedules and | 1.0 | 1.0 | 1.0 | 3.5 | 4.0 | 5.0 |

**D – STUDIO AMBIANCE**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| D1 | The ambiance during the review is formal/professional/task oriented | 3.0 | 2.9 | 4.7 | 5.0 | 4.5 | 5.0 |
| D2 | The ambiance during the review is 'social' – encourages informal interaction | 3.0 | 2.8 | 1.0 | 1.0 | 1.8 | 1.0 |
| D3 | The reviewer(s) act(s) as an expert/source of authority | 1.5 | 3.6 | 5.0 | 5.0 | 4.8 | 5.0 |
| D4 | The reviewer(s) act(s) as a supporting "buddy" | 1.5 | 1.9 | 1.0 | 1.0 | 1.8 | 2.0 |
| D5 | The reviewer(s) act(s) as a coach/facilitator | 2.5 | 4.4 | 1.3 | 2.8 | 3.5 | 5.0 |
| D6 | Peers participate in reviews | 2.5 | 2.1 | 1.0 | 1.0 | 1.0 | 4.0 |

## Biographies

Gabriela Goldschmidt is a Professor Emeritus in the Faculty of Architecture and Town Planning at the Technion – Israel Institute of Technology. She holds a MArch from Yale University and has served as a Visiting Professor at various universities. Her research interests include design cognition and learning, and visual thinking.

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Ori Ronen studies for a Behavioral Sciences master's degree in the Faculty of Industrial Engineering and Management at the Technion – Israel Institute of Technology. He holds a BArch from the Technion, and specialized in architectural conservation at the POLIMI, Milano. His fields of interest include design creativity and cognition.