Design Grammar - a pedagogical approach for observing teacher and student interaction

João Ferreira
TU Delft, Delft, The Netherlands
j.c.batalheirocorticoribeirof@tudelft.nl

Henri Christiaans
TU Delft, Delft, The Netherlands
3h.h.c.m.christiaans@tudelft.nl

Rita Almendra
Lisbon University, Lisbon, Portugal
almendra@fa.utl.pt

Abstract: Teacher and student interaction in a design-studio setting, also referred to as tutorial-learning or learning-by-doing, has been the blueprint of design education for decades. A crucial difficulty of design education is that the content of these meetings remains remarkably implicit.

In this study we propose to explore the concept of Design Grammar as an observation framework for teacher-student interactions. Design grammar can be defined as the visual language used to design, i.e., the elements, and relationships between them, that are synthesized in the Form (understood as a unified structure of parts) of an artifact. In order to make this concept operational we developed a Design Grammar Model (DGM) which explicits the different elements involved in form-giving in design.

We used the DGM to analyze the content of the interactions of junior Industrial Design students. We compared the results in terms of the student and teacher's fluency in Design Grammar (DG), the criteria to evaluate fluency was: the frequency of references to DG, variety of references and articulation of DG elements.

The main insight of our study was the observation that interactions with students with lower fluency in DG resulted in poorer performances from the teacher and therefore lower quality interactions.

Keywords: Design Grammar, Design Education, Observational study.

1. Research question

What is the influence of Design Grammar for teacher-student interaction in a design-studio setting?

Sub-question(s)

- To what extent does a student's fluency on Design Grammar influence the interaction with the teacher.

- How does it differ in different stages of project development.

2. Theoretical Framework

This study explores the concept of Design Grammar as a basis for observing teacher-student interaction in a design-studio setting.

In general, Design Grammar can be understood as the *visual language* used to design, that is, the elements, and relationships between them, that are synthesized in the **Form** (understood as a unified structure of parts) of an artifact.

The concept of Design Grammar we present here is rooted, originally, in the general pedagogical principles developed in the Bauhaus (1919-1933). Johannes Itten (1963) organized the first basic foundation course in the Bauhaus, this course was the first attempt to establish a formal educational approach to the study of the basic materials, principles, and elements of forms. The blueprint developed by Itten would become a model for visual education (Wallschlaeger, et al., 1992) and was later adopted by Design courses across Europe and the USA. The Bauhaus foundation course was focused on establishing a foundation for the abstract study of form, but this was a part of the Bauhaus curriculum as a whole, which included an understanding of the crafts as well as the technological developments in manufacturing of the age.

As was stated before, the Bauhaus pedagogical approach was highly influential for Design education. The Ulm School of Design built on this foundation when developing their Basic Design (or propaedeutic) Courses. The Ulm School of Design's life was short (1955-1968) but nevertheless offered a significant contribution for design education. Building on the Bauhaus legacy, Max Bill, the school's founder, insisted on the idea of a systematic study of visual education and form-giving, and introduced the study of semiotics into the curriculum (a feature present in most Product Design courses since.)

As long as there is a Product Design course, the problem of how to teach form-giving remains fundamentally unchanged.

"To design the form means to coordinate, integrate and articulate every factor that, in some way or another, takes part in the constitutive process of a product's form. And, more precisely referring either to usability related factors, fruition and individual or social consumption of the product (functional, symbolic or cultural factors) as well as those who relate with its production (economical, technical, constructive, systemic, productive or distributive factors.)" (Maldonado, 1991, p.14)

Therefore, 'form' in product design is the result of a synthesis that includes all the dimensions mentioned in the above quote. Different schools of thought may emphasize some aspects over others, but the synthesizing role of the designer is crucial nonetheless. The designer overviews the complex interconnection and has the responsibility to provide a meaningful solution. To give form, *to form* in this sense, is what designers do, it is their craft. Thus designers take on a decisive role in building the human environment.

Pedagogical implications

From a pedagogical perspective, Design Grammar could serve an important mediation role (as a common language) between teacher and student, by providing a common ground between unexperienced student and expert teacher, being here highly relevant the work of Donald Schon (1987.)

Design education is traditionally based on a process of apprenticeship. Students practice the role of designing during projects, while being tutored by an experienced designer. Thus, there is a substantial emphasis on teacher and student interaction. Most courses will have a systematic, scientific based approach for teaching the relevant sub-disciplines (such as ergonomics, computer assisted design, design history, technology, design theory, and so on) while the actual process of learning *how* to design is alluded through exercises and tutoring, and expected to be developed tacitly as students mature through the years in the course.

A crucial difficulty of the 'learning by doing' paradigm in design is that designers find it difficult to make explicit what they know, their knowledge of their own processes of designing remains mainly tacit knowledge (Polanyi, 2009). The intricacies of the 'dialogue' (expressed verbally or visually) between tutor and pupil in the design studio have been emphasized before as well as the importance of maintaining and encouraging refection during the learning process (Dewey, 1998; Schön, 1987).

Design Grammar has the potential to render part of the content of the teacher-student interaction more explicit. This way, we open the possibility to explicit gaps between the design grammar knowledge of the teacher and the students, as well as a way to monitor student's progress, and thus offering teachers a possible tool to nurture the student's development.

2.1 The Design Grammar Model (DGM)

We propose to use Design Grammar (DG) as a framework for observing teacher and student interactions in a design-studio setting (i.e. while student and teacher work in a design project). In order to do this, we developed a model to operationalize the concept of DG.

Let us recover the previously presented definition:

"In general, Design Grammar can be understood as the *visual language* used to design, that is, the elements, and relationships between them, that are synthesized in the **Form** (understood as a unified structure of parts) of an artifact."

We delved into decades of educational experiments in this field and worked on a synthesis of the several elements considered fundamental (or foundational) throughout time. It would be anachronistic to adhere to one school of thought fundamentally (whether the Ulm school or Bauhaus or other.) Therefore we developed a synthesis of the different models which we present bellow (Figure 1.)

The model is descriptive, it is not rigidly hierarchical, and the interconnectedness is key; as such, we developed the model in a tree-shaped diagram. Thus, the central trunk represents the *unity of form* – the unifying structure or synthesis of parts; and each branch represents broad areas that establish guidelines but are not an exhaustive description of each area. The areas are defined with enough precision to be able to offer a guideline for categorization.
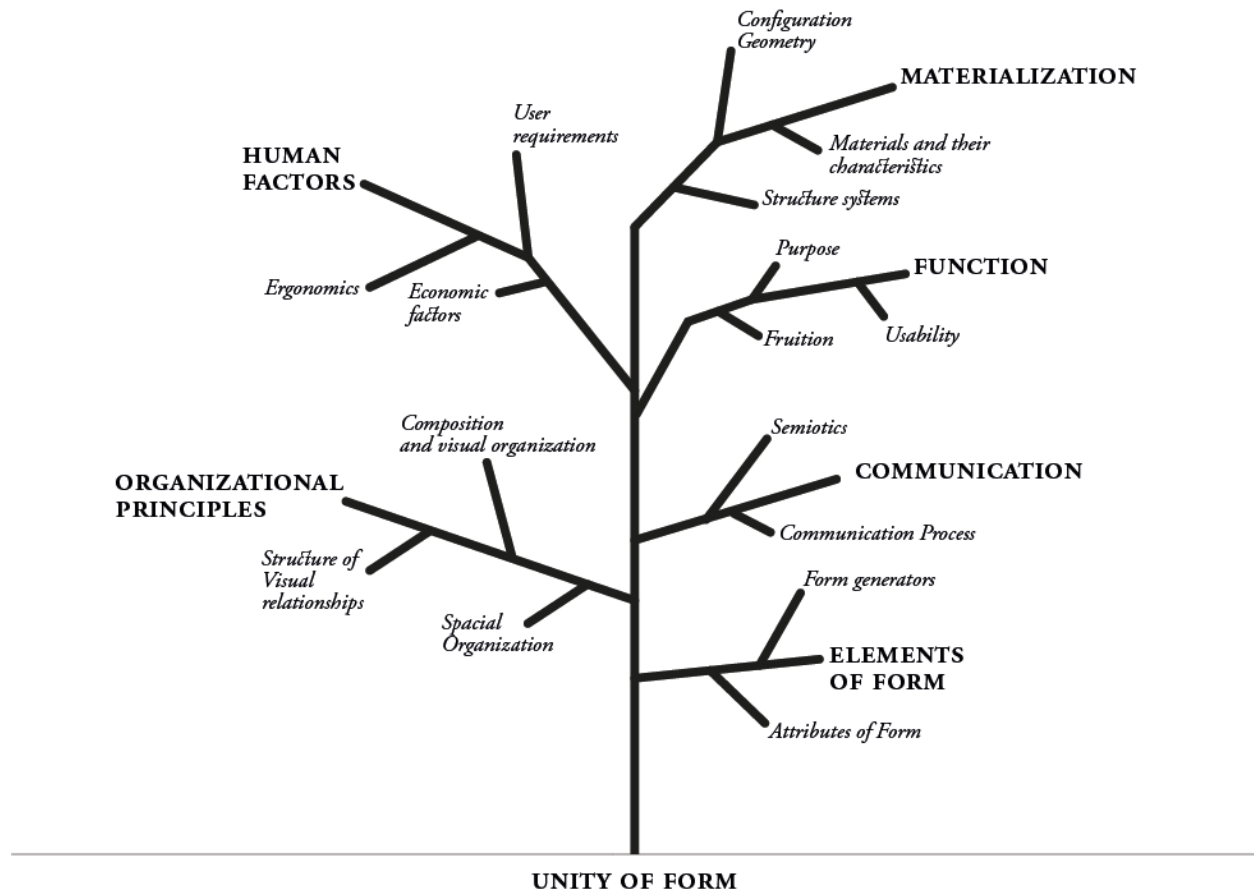
Figure 1. Design Grammar Model (DGM)

Description of Design Grammar elements

What follows is a general description of each category, each sub-category is assigned a code to facilitate its use when using the DGM as a framework for analysis of the transcripts.

Elements of Form: includes the most basic and foundational elements of form (point, line and plane) which are the form generators; the combination of these three elements results in the creation of Volume (positive and negative space); as well as the attributes of form: dimensions, texture, value (light-dark,) shape (triangle, circle, square) and color.

- Form generators (E1)

- Attributes of form (E2)

Organizational Principles: concern the aspects of *composition*, *structure* and *spatial* organization, it is a step beyond the Elements of Form in the sense that these principles address the visual relationships between different parts, between parts and whole, and further explores the transition between 2 and 3 dimensions.

- Composition and visual organization (O1): Balance (symmetrical, asymmetrical) repetition, harmony, rhythm, contrast, variety.

- Spacial organization (O2): centralized, linear, radial, clustered, grid.

- Structure of visual relationships (O3): Dominant, subdominant, subordinate; rectilinear, curvilinear.

As was stated before, the model is not rigidly hierarchical. However, there is an important distinction to be made between the *Elements of Form* and *Organizational Principles,* and the other categories of the model. These two categories correspond to a Basic Design Grammar; a set of principles and elements which are purely abstract, much in the same way as musical notes, chords and scales function in music. That is, a musical note holds no more meaning than a line in space. It is the combination of notes within a certain structure (rhythmic, harmonic and so forth) as well as the context of the listening experience that conveys a certain emotion to the listener. Of course, this analogy only holds for Design to a degree, since Design is not a purely artistic endeavor.

Communication: refers to the artifact as part of the artificial world and material culture, it concerns the implications of understanding an object as a *sign,* that is, the meaning(s) it conveys in a communication process. Product Design generates material reality, satisfying practical functions and technical performance are only a part of that reality, a design product also deals with connotations.

- Semiotics (C1)

- Communication process (C2)

Function: a crucial aspect of design, *function* refers to the product's <u>purpose</u> (what needs it is intended to fulfill) <u>usability</u> (the ability to be used, ease of use) and fruition (enjoyment, a pleasurable possession.)

- Purpose (F1): an object's reason of existence, the needs it is intended to fulfill.

- Usability (F2): concerns the way a product functions, or its ease of use.

- Fruition (F3): from its original meaning (Burchfield, 2004) of enjoyment, a pleasurable possession, to enjoy.

Human Factors: these refer to specific requirements that constrain the object. It includes Ergonomics, User Requirements and Economic factors.

- User requirements (H1): any specific constraint or special requirement related with the users.

- Ergonomics (H2): anthropometric issues.

- Economic factors (H3): overall costs (specially regarding manufacture).

Materialization: refers to aspects concerning the actual physical materialization of the product; these include <u>materials</u> and their characteristics (manufacturing technologies, available tools and

machinery etc) <u>structure</u> (dynamic or static, forces and equilibrium, specific structural parts) and <u>configuration</u> (geometric solutions and real dimensions of the object.)

- Materials (M1)
- Structure (M2)
- Configuration (M3)

3. Methods

Our study explores the application of the Design Grammar model as an analysis framework to observe teacher-student interaction.

The research uses the Industrial Design (junior students) database. Within the database our study focused solely on the recordings of teacher-student interaction. Therefore, client presentation recordings, for instance, were not analyzed. We made use of the video-recordings as well as the transcripts.

In earlier drafts of this study we explored the possibility of also looking into the Industrial Design (graduate students) database. However, the fact that the graduate students reviews were based on a group dynamic, would prevent us from applying the same observation framework and therefore we abandoned the idea of including the graduate students in our observations.

For our analysis approach we have developed an observational framework which we will now present.

The observational framework is divided in 3 sequential phases:

- Phase A: Identification of *events* and primary analysis.
- Phase B: Categorization of *events;*
- Phase C: In depth analysis.

Events are a short interaction, during the dialogue between teacher and student, that activates the researcher's focus, i.e. during the observation of the video-recordings and transcripts we will search for references to form-giving. These references can be verbal or non-verbal (e.g. sketches, gestures, examples.) Identifying the events concludes **phase A**. It is important to note that, in this study, analysis of non-verbal interactions are problematic: it is possible to identify moments when the teacher or student is drawing, however, the content of the drawings are almost impossible to determine in the videos. Therefore, the moments of non-verbal interaction are recognized but not categorized.

During **phase B** the *events* are categorized according to the DGM categories, the analysis focuses on both the teacher and the student's input. This information is structured and categorized using an analysis table (fragment of an analysis table bellow):

Table 1. Example of an analysis table

Video: First review Todd				
Teacher/Student	Event / Time	Transcript	Notes	**Design Grammar analysis**
Teacher *Gary*	**8.** *07.40*	Now keep in mind you pull it off, it's gonna – where's it gonna go? Is it gonna go down pretty much, stand on it?		- Structure (M2)
Student *Todd*	**10.** *07.43*	Go down and then like it would be under your legs, basically. Um, it's kinda a rough idea, but it's kind of out there, you know?		- Structure (M2) - Ergonomics (H2) (under your legs) **Articulated** *(overall structure choice affects ergonomics)*

At this stage (B) the analysis focuses on two questions:
2. Is the subject (teacher or student) expressing information which can be described by a DGM category, and
3. Are the DG elements articulated with each other and/or with the whole?

The combination of both criteria serves the purpose of analyzing the Design Grammar *fluency* of the subject. The criteria for fluency analysis is: frequency and variety of DG references, and also if they are *articulated*. While frequency and variety analysis is straightforward and objective, the evaluation of *articulation* is more subjective. It is not enough that two (or more) elements of DG are mentioned in the same event for it to qualify as *articulated*; there has to a meaningful relationship between the elements. Perhaps an example might illustrate the point:

Articulated example:

Table 2. Fragment of analysis table – e.g. of articulated categorization

Student *Lynn*	**13.** *08.30*	And this one is actually just one piece, and you fold it and you create a shape like this. And easy for you to, ah, place it, easy for you to install it.	- Points to drawing while talking.	- Structure (M2) - Usability (F2) **Articulated**

The reference to structural issues (one piece, foldable) is related to ease of use (*"easy for you to install it"*).

Non-articulated example:

Table 3. Fragment of analysis table – e.g. of non-articulated categorization

Teacher *Gary*	**5.** *09.40*	This is gonna be your, your biggest challenge is trying to get your geometry, right	- Points to drawing	- Configuration (M3)

Clearly, an isolated reference to an issue of *configuration*.

After completing the analysis table, we structure the data resulting from the categorization in a series of tables which serve the purpose of making an overall statistical analysis.

At this stage, and still within phase B, we use the tables to develop a series of diagrams which will sustain the in-depth analysis of phase C. These diagrams do not contain information which is not present either in the analysis or the statistical tables. However, the diagrams serve the purpose of displaying the information visually in an immediate way, and therefore allow for an overall perspective of the teacher-student interactions. What follows is a brief explanation of how the diagrams are designed.

Diagram design

The diagram (figure 2) consists of 6 triangles which represent the 6 areas of the design grammar model. The triangles are placed inside a circle which reinforces the idea of the unity of form.

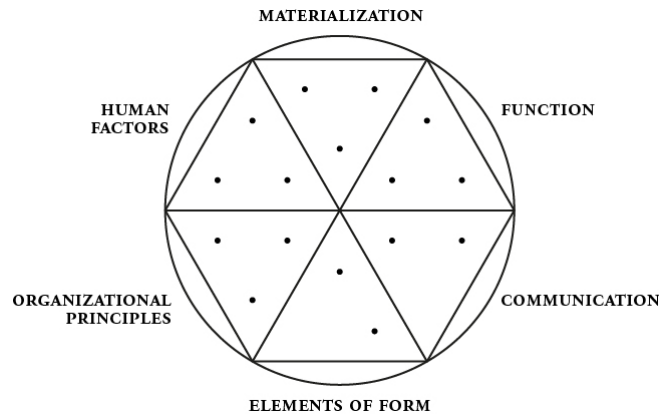The black dots represent the sub-categories of each area.

Figure 2. Design grammar diagram

We created a diagram for each event of every interaction. The dotted lines represent an articulation between elements. See an example on figure 3 bellow.
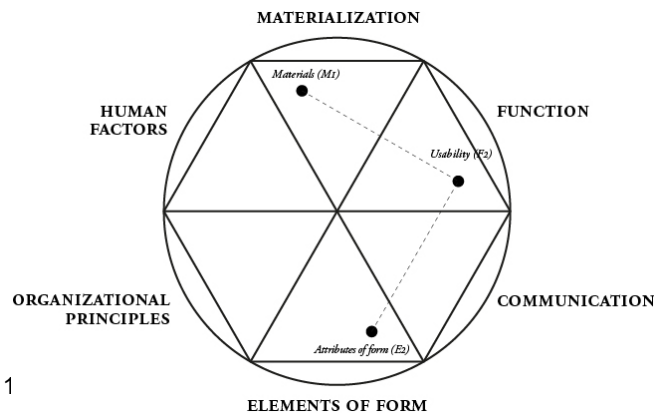
Figure 3. Example of single event diagram

After completing the diagrams for every event, the data is used to create an *overall diagram*, that overlays all the single event diagrams. In the overall diagram the black circles expand in proportion to number of references made and all the articulation lines are displayed as well.

The overall diagram enables us to understand where the focus of the interaction was centered and what connections were established. Furthermore it offers another tool of immediate comparison between teacher and student as well as between different students.

In **phase C** we work with the data resulting from the previous phases and perform an in-depth analysis of each teacher-student interaction focusing on:

- Comparing students with different DG fluency.
- Comparing the teacher's role when interacting with students with different DG fluency.
- Does a different DG fluency have an effect on the teacher-student interaction? In what way(s).
- Comparing the interactions in different stages of project development; is there a difference regarding the content of the *events*?

The articulation of these questions primarily attempts to explore the issue of Design Grammar as a common language (*mediation*) between teacher and student.

Table 4. Summary of methods

PHASE	OBJECTIVES	METHODS (mixed methods approach)	OUTPUTS
Phase A	Identification of events	1. Observation of video-recordings. 2. Reading the transcripts.	- Preliminary analysis table
Phase B	Categorization of events	1. Categorization of events according to DGM. 2. Statistical analysis of results. 3. Development of interaction diagrams.	- Final analysis table - Statistical tables - Interaction diagrams
Phase C	In depth analysis	Crossing of outputs resulting from phases A and B.	- Qualitative analysis of each interaction. - Answering the research questions. - Overall discussion and conclusions

4. Results

4.1 Context

The dataset

For our study we are interested in teacher-student individual interaction. The industrial design junior dataset includes the video recordings and transcripts of 7 students; and it is divided in 5 stages of project development: 1st review, 2nd review, client review, look like review, and final review (see table 3 bellow), of these we have focused solely on the ones involving teacher-student meetings; this means that the client and final review were not analyzed in our study.

Table 5. Students and project stages

	Lynn	Todd	Adam	Alice	Sheryl	Addison	Esther
1st Review	x	x					
2nd Review			x	x	x		
Client review	x	x	x	x	x	x	x
Look like review		x			x	x	x
Final review		x	x	x	x	x	x

Therefore the study focused on 9 different interactions spread across 3 stages of project development: two in the 1st review, three during the 2nd review and four during the look like review.

Unfortunately it was not possible to follow all the students' progress across the different stages (1st, 2nd and look-like review). There are video-recordings of Sheryl and Todd in two different moments, but the majority of data concerns only one interaction with the teacher. Therefore, it is not possible to analyze the teacher-student interaction's evolution.

Briefing

The briefing the students were working on read as follows:

"Design Brief on "Impromptu Seating" Project with Office Furniture Company.

The seating is to be very casual and provide "impromptu" seating for individuals and small meetings. This new seating concept can also add color and unique forms to a basically sterile and safe offices cape as typical office colors are typically muted and neutral. Consider your concept pieces as accessories that can bring excitement to the office."

There were also specific constraints regarding overall dimensions and suggestions concerning possible material solutions.

The project consisted of individual work and the students had roughly two months to complete it (October the 7th until December the 6th 2013).

4.2 Overall analysis

During this study we identified a total of 250 events. The number of events is relatively balanced between students and teacher, with a slight edge for the teacher who was responsible for 144 events (57,6%) while the students' total was 106 (42,4%).

Table 6. Total events

	1st review (2 interactions)	2nd review (3 interactions)	Look-like review (4 interactions)	Total events (9 interactions)
Teacher (Gary)	35	60	49	**144**
Students	38	34	34	**106**

It is worth noting that even though there are only two interactions in the 1st review, the number of registered events is similar to the later stages (specially in the students' case 38-34-34.) Comparatively, the look-like review registers the highest number of interactions (4) but there is not a subsequent increase in the number of events. This suggests that the earlier stages of project development are richer in frequency of events.

Design Grammar categorization

We identified a total of 469 design grammar categorizations during the study. The student's register 171 (36,4%) while the teacher measures 298 (63,6%).

While the total number of events was somewhat balanced between students and teacher (with a slight edge for the latter) when we look into the detail of the events, the teacher represents almost two thirds of all categorizations. This indicates that the teacher's events were richer in terms of design grammar frequency.

In tables 7 and 8 (bellow) we can see this information in more detail.

Table 7. DG categorization (students' total)

		Students			
		1st review	2nd review	Look like review	**TOTAL**
Elements of form	Form generators	6	1	0	7
	Attributes of form	10	6	1	17
		16	**7**	**1**	**24 (14%)**
Organizational principles	Composition and visual organization	0	1	3	4
	Spatial organization	1	0	0	1
	Structure of visual relationships	0	1	0	1
		2*	**2**	**3**	**7* (4%)**
Communication	Semiotics	2	0	0	2
	Communication process	0	0	0	0
		2	**0**	**0**	**2 (1,1%)**
Human factors	User requirements	0	1	0	1
	Ergonomics	1	0	0	1
	Economic factors	2	0	2	4
		3	**1**	**2**	**6 (3,5%)**

Materialization	Materials	8	11	9	28
	Structure	14	4	7	25
	Configuration	6	9	9	24
		28	**24**	**25**	**77 (45%)**
Function	Purpose	5	8	1	14
	Usability	20	11	7	38
	Fruition	2	1	0	3
		27	**20**	**8**	**55 (32,1%)**
					171

Table 8. DG categorization (teacher's total)

		Teacher			
		1st review	2nd review	Look like review	**TOTAL**
Elements of form	Form generators	2	0	0	2
	Attributes of form	13	9	6	28
		15	**9**	**6**	**30 (10,1 %)**
Organizational principles	Composition and visual organization	1	5	4	10
	Spatial organization	0	1	1	2
	Structure of visual relationships	0	2	0	2
		6*	**9***	**5**	**20* (6,7%)**
Communication	Semiotics	2	2	0	4
	Communication process	1	0	0	1
		3	**2**	**0**	**5 (1,6%)**
Human factors	User requirements	4	2	0	6
	Ergonomics	6	6	4	16
	Economic factors	9	2	0	11
		19	**10**	**4**	**33 (11,1%)**
Materialization	Materials	18	27	20	65
	Structure	13	14	20	47
	Configuration	10	26	13	49
		41	**67**	**53**	**161 (54%)**
Function	Purpose	3	6	4	13
	Usability	12	10	4	26
	Fruition	7	3	0	10

		22	19	8	49 (16,4%)
					298

* The Organizational Principles category was hard to sub-categorize. Frequently we could not agree on which sub-category a certain even referred to, in these cases we considered the category as a whole. That is the reason why adding all the sub-categorizations results in a smaller number than the total.

The overall categorization tables also give us further data to compare. For instance, we can observe that both teacher and students focused on the category of *materialization* (students 45% and teacher 56%). This is a constant across the 3 different stages, that is, *materialization* is the category with the highest frequency for both students and teacher. *Communication* is the category with the lowest score (a residual 1,1% for students and 1,6% for teacher) which could be explained by the nature of the briefing, i.e., neither teacher nor students were interested in exploring the meanings and connotations of the "impromptu seating in office space," the meaning was already fairly established *a priori* in the briefing.

There is a considerable difference regarding the *human factors* category; it had a residual score on the students' side (3,5%) whereas the teacher registered 11,1%.

Finally, a first overall analysis also reveals that all categories (except materialization) decrease in frequency as the project progresses. The combination of this finding with the previous observation that the frequency of events also declines as the project advances, reinforces the idea that earlier stages of project development are richer in content than later stages. We will discuss this insight during the discussion part of the paper.

4.3 Individual student analysis

Interaction 1: Lynn, 1ˢᵗ review

Lynn and Gary (teacher) had a 26.16 minutes interaction during which we registered 39 events spread equally (20-19) between the two. The number of categorizations was also fairly balanced (Lynn had 48 and Gary 43).

Table 9. DG Lynn – first review

		Lynn	Gary
Elements of form	Form generators	3 (6,25%)	2 (4,6%)
	Attributes of form	8 (16,6%)	8 (18,6%)
		11 (22,9%)	**10 (23,2%)**
Organizational principles	Composition and visual organization	0	1 (2,3%)
	Spatial organization	0	0
	Structure of visual relationships	0	0
		0	**2 (4,6%)***
Communication	Semiotics	1 (2%)	1 (2,3%)

	Communication process	0	1 (2,3%)
		1 (2%)	**2 (4,6%)**
Human factors	User requirements	0	1 (2,3%)
	Ergonomics	0	4 (9,3%)
	Economic factors	0	5 (11,6%)
		0	**10 (23,2%)**
Materialization	Materials	6 (12,5%)	7 (16,2%)
	Structure	7 (14,5%)	3 (6,9%)
	Configuration	3 (6,25%)	5 (11,6%)
		17 (35,4%)	**15 (34,8%)**
Function	Purpose	4 (8,3%)	0
	Usability	14 (29,1%)	6 (13,9 %)
	Fruition	2 (4,1%)	3 (6,9%)
		20 (41,6%)	**9 (20,9%)**
Total		**48**	**43**
Duration of interaction		26:16:00	
Number of events		20	19

Fluency

Considering the *frequency* of design grammar elements, Lynn was, as we can observe in table 7, on par with the teacher. However, delving into the *variety* of categorizations, there is a clear discrepancy in the *Human factors* category: we did not observe any mention of Human factors' issues from Lynn, whereas Gary's human factors references made up 23,2% of his total.

Lynn's events had a very clear focus on the *elements of form, function*, and *materialization*, with a distinct emphasis on *function* (41,6%).

Figure 4 (bellow) displays both participants' overall diagrams side-by-side, which allows for an overall perspective of the interaction.
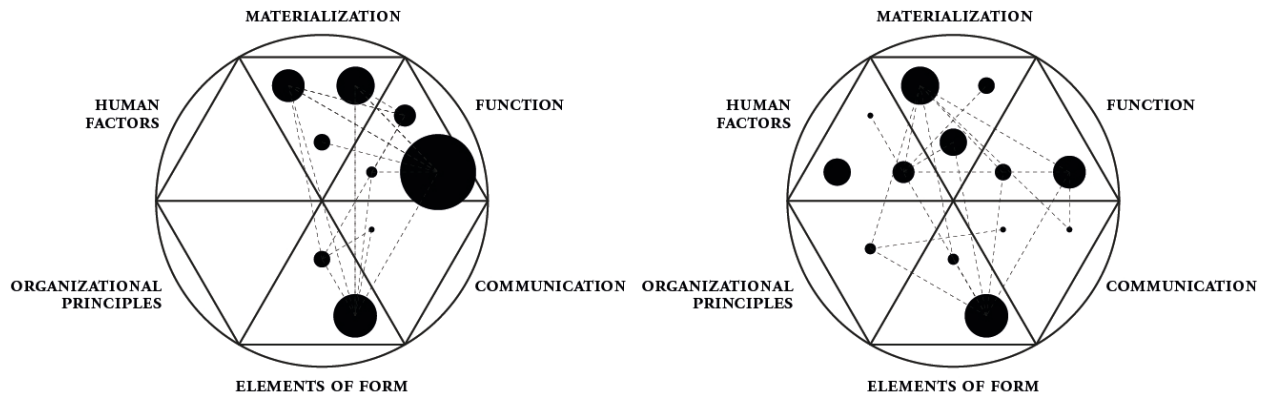
Figure 4. Diagrams of Lynn (left) and Gary's (right) interaction

Lynn's focus on *function* related issues becomes visually very clear. Her diagram also shows that the different elements were articulated with each other. Observing the teacher's diagram we realize that it does not follow Lynn's pattern; Gary's diagram displays a balanced distribution of DG elements. It is interesting to note that one of the elements of *human factors* (namely H3, economic factors) is mentioned several times but is never articulated with the other elements.

Mediation

A first analysis of Lynn's data suggests a balanced interaction between teacher and student (similar frequency of events and categorizations.) However, an in-depth analysis as already showed relevant differences between the two.

Going back to the transcripts also reveals another important issue regarding the dialogue between teacher and student: of Lynn's total of 20 events, 14 occurred in the first 8 minutes of interaction, furthermore, during that 8 minute period, the teacher registers only 4 events. This suggests that the interaction was not a fluid back-and-forth dialogue between the two; instead, the meeting could be divided in two moments: the first 8 minutes correspond to the bulk of Lynn's interaction and the remaining 12 to Gary's.

Interaction 2: Todd, 1st review

Todd and Gary had a 20.40 minutes interaction during which we registered 44 events. Unlike Lynn (Interaction 1) the frequency of events was clearly skewed towards the teacher (18 – 26), the imbalance is reinforced with the number of categorizations tending for the teacher (30 – 58).

Table 10. DG Todd – 1st review

		Todd	Gary
Elements of form	Form generators	3 (10%)	0
	Attributes of form	2 (6,6%)	5 (8,6%)
		5 (16,6%)	**5 (8,6%)**
Organizational principles	Composition and visual organization	0	0
	Spatial organization	1 (3,3%)	0

	Structure of visual relationships	0	0
		2 (6,6%)*	**4 (6,8%)***
Communication	Semiotics	1 (3,3%)	1 (1,7%)
	Communication process	0	0
		1 (3,3%)	**1 (1,7%)**
Human factors	User requirements	0	3 (5,1%)
	Ergonomics	1 (3,3%)	2 (3,4%)
	Economic factors	2 (6,6%)	4 (6,8%)
		3 (10%)	**9 (15,5%)**
Materialization	Materials	2 (6,6%)	11 (18,9%)
	Structure	7 (23,3%)	10 (17,2%)
	Configuration	3 (10%)	5 (8,6%)
		12 (40%)	**26 (44,8%)**
Function	Purpose	1 (3,3%)	3 (5,1%)
	Usability	6 (20%)	6 (10,3%)
	Fruition	0	4 (6,8%)
		7 (23,3%)	**13 (22,4%)**
Total		**30**	**58**
Duration of interaction		20:40:00	
Number of events		18	26

Fluency

It is interesting to note that Todd focused on the same elements as the teacher (the percentages are similar with the exception of *elements of form*). The significant difference in *frequency* did not correlate with a difference in *variety*. In short, Todd had less events but they were focused on the same issues as the teacher.

This is clear when observing both diagrams (Figure 5). While the spread of elements is similar, the frequency is more intense on the teacher's diagram. Todd's diagram also display his overall articulation of the several elements.
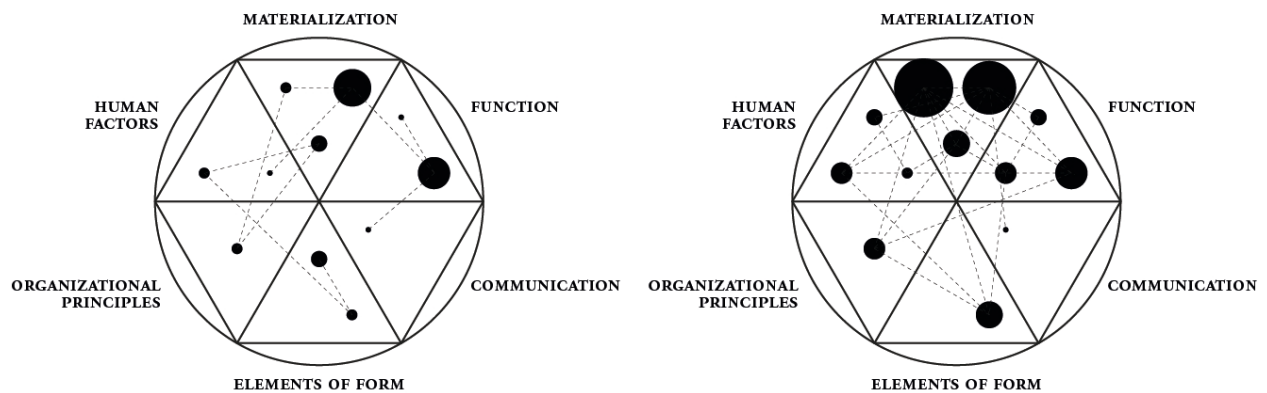
Figure 5. Diagrams of Todd (left) and Gary's (right) interaction

Mediation

It is interesting to notice that up until the 11 minute mark Todd had registered 16 events and the teacher 17. Considering that the interaction lasted 20.40 minutes, this means that up until that point the dialogue had been almost a perfect back-and-forth balance between the two. There is an interesting part of the interaction which is worth highlighting; at one point during this first half of the interaction, the teacher heavily encourages the student regarding one of the proposals (one the student was not very convinced about pursuing) this is evident in the following transcript (around the 7.30 minute mark):

Todd "This isn't really, because I don't think they fit on top of each other. I mean they, they could. That might look cool if they were all stacked."

Gary "That creates – to me – I saw that neat little tension. It creates tension, which is kind of neat. (...) You know? And so which offers, and then you could have different materials and colors, but I think there's something unique – about that because it, it is different and it's take – it's geometry, but, you know, you were saying like if you put it in a different context."

Todd: "yeah. So that's the final idea I like, too."

This passage illustrates that (at least during the first half of the interaction) the teacher and student were engaged with the project, discussing ideas as well as making decisions. This is further reinforced since it is possible, while following this passage in the video-recording, to identify the idea (expressed in Todd's drawings) they are discussing, and this idea was in fact developed further and became the main concept Todd presented at the end of the project (Figure 6 bellow).
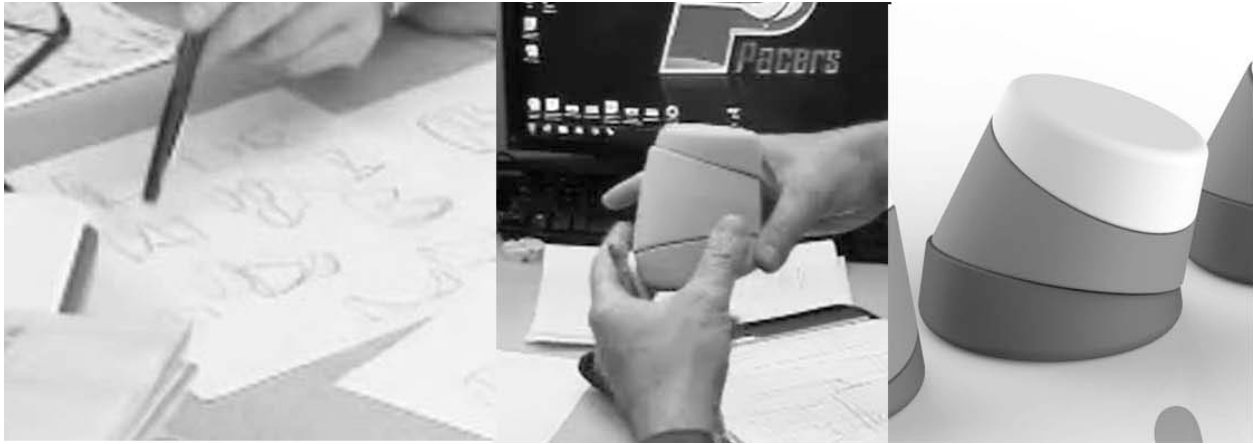
Figure 6. Left to right (1st review sketch, look-like model, final presentation)

Thus, the overall imbalance in frequency of events happens in the remaining 9 minutes of the meeting, where the teacher is going through the proposals Todd had presented before. The previous 11 minutes corresponded to an overall balanced dialogue driven by both Todd and Gary. Furthermore, identifying an important decision-making event adds weight to the idea that initial stages of the design process are crucial for project development.

Interaction 3: Adam, 2nd review

Interaction 3 occurs during the 2nd review between Adam and Gary. It lasts 16.13 minutes and therefore is shorter than both interactions observed in the 1st review. The teacher almost doubles the number of events of Adam (23 – 12); categorization is also unbalanced towards the teacher (40 – 19).

Table 11. DG Adam – 2nd review

		Adam	Gary
Elements of form	Form generators	0	0
	Attributes of form	4 (21%)	4 (10%)
		4 (21%)	**4 (10%)**
Organizational principles	Composition and visual organization	0	3 (7,5%)
	Spatial organization	0	1 (2,5%)
	Structure of visual relationships	1	2 (5%)
		1 (5,2%)	**6 (15%)**
Communication	Semiotics	0	1 (2,5%)
	Communication process	0	0
		0	**1 (2,5%)**
Human factors	User requirements	1 (5,2%)	1 (2,5%)

	Ergonomics	0	4 (10%)
	Economic factors	0	0
		1 (5,2%)	**5 (12,5%)**
Materialization	Materials	4 (21%)	6 (15%)
	Structure	2 (10,5%)	4 (10%)
	Configuration	1 (5,2%)	8 (20%)
		7 (36,8%)	**18 (45%)**
Function	Purpose	2 (10,5%)	2 (5%)
	Usability	4 (21%)	4 (10%)
	Fruition	0	0
		6 (31,5%)	**6 (15%)**
Total		**19**	**40**
Duration of interaction		16:13:00	
Number of events		12	23

Fluency

Concerning the categories of DG, Adam and Gary differ in every category. Adam focused on the elements of form (21%), materialization (36,8%) and function (31,5%), whereas Gary had a very clear focus on materialization (45%) and the remaining categories were more evenly spread.

Adam's events are short but rich with references to DG elements; below we can see a couple of transcripts that illustrate his overall approach.

"I know. I'm thinking I want to make the out of fabric so they can play around with it a lot. But right off the bat, I was thinking I'd make it in like dual colors." (materials [M1] and attributes of form [E2])

"Um, this one, going along with stacked idea. Ah, it's a simpler shape, but it's got a little cushion on top, and the roller recessed edge on the bottom so then you can stack them on top of – one another." (materials [M1], usability [F2], configuration [M3])

The diagrams (figure 7) illustrate Adam's focus more clearly as we observe that the articulations occurred mostly between the *materialization*, *function* and *elements of form* categories.
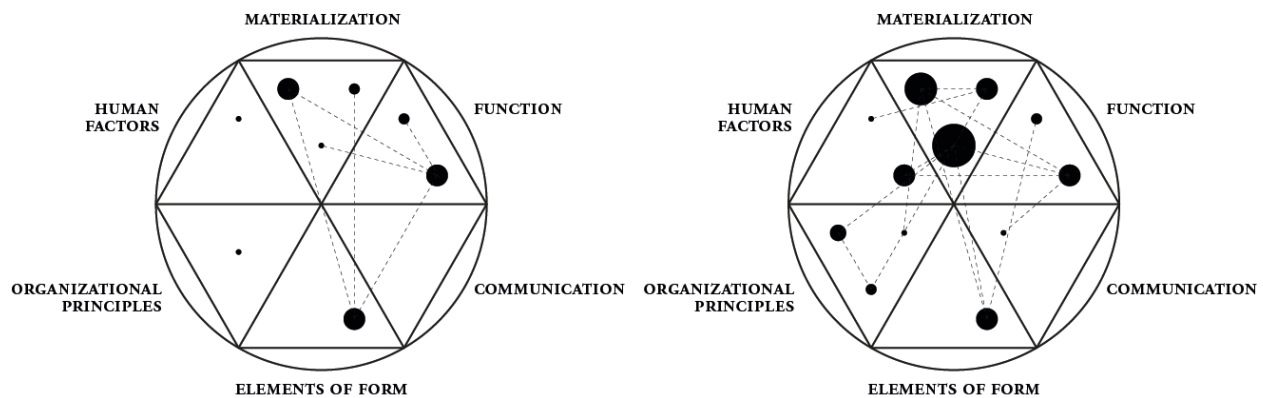
Figure 7. Diagrams of Adam (left) and Gary's (right) interaction

Mediation

This was a very interesting interaction. A first look at the data suggests a rather unequal dialogue between teacher and student, specially if we consider the total number of categorizations (19 – 40). The participants also differed substantially in the focus of the interaction: Adam clearly focusing on materialization, function and elements of form, while Gary spread his DG references more widely.

However, a close analysis reveals the opposite. The dialogue had more input from the teacher, but it was driven by both teacher and student equally (specially in the first 10 minutes.) Adam's lower input in terms of frequency of events could be explained by his overall dry and direct approach (short, meaningful sentences).

During the first 10 minutes there were several moments when the participants were finishing each other's sentences, something that can only be fully observed in the video-recordings, but bellow we present a transcript of one such moment:

Gary- "Um, this is, this is better. I mean if you get the same – I would – I would make that between the bases or the, that you – that it – I would probably make 'em the same. Try to come up with the symmetry."

Adam- "Okay. 'Cause I think part of the appeal of this is that it is big – it curves in."

In the above transcript Gary and Adam say "it curves in" at the same time while making a gesture indicating the curvature.

Another highlight occurred around the 3.00 minute mark, the teacher began to draw extensively in his own notepad, something that was seldom observed (at least, with such intensity) during the course of this study. Below we present the transcript of the beginning of the moment (Gary was speaking while drawing).

"Who knows? Once – we gotta lay it out to make sure you could you got some comfort there. Maybe what happens is maybe it doesn't split down the center. Maybe it's more, I guess you mean, something like this – That way you get the base dimension (...) is closer."

For about a minute both interacted while the teacher was drawing.

The marked differenced in focus of DG categories could, perhaps, be understood as a complementary approach by the teacher, in similar fashion to Gary's focus on *human factors* during Lynn's interaction (interaction 1).

Interaction 4: Alice, 2nd review

Alice's interaction lasted 22.00 minutes, which is a number closer to the ones registered during the 1st reviews. This could be explained by the observation that Alice, unlike Adam, was still unsure about what ideas she should develop further. The teacher registers a higher number of events (24 – 18) as well as categorizations (47 – 30).

Table 12. DG Alice – 2nd review

		Alice	Gary
Elements of form	Form generators	1 (3,3%)	0
	Attributes of form	2 (6,6%)	2 (4,2%)
		3 (10%)	**2 (4,2%)**
Organizational principles	Composition and visual organization	1 (3,3%)	2 (4,2%)
	Spatial organization	0	0
	Structure of visual relationships	0	0
		1 (3,3%)	**2 (4,2%)**
Communication	Semiotics	0	0
	Communication process	0	0
		0	**0**
Human factors	User requirements	0	1 (2,1%)
	Ergonomics	0	1 (2,1%)
	Economic factors	0	1 (2,1%)
		0	**3 (6,3%)**
Materialization	Materials	4 (13,3%)	11 (23,4%)
	Structure	2 (6,6%)	6 (12,7%)
	Configuration	7 (23,3%)	12 (25,3%)
		13 (43,3%)	**29 (61,7%)**
Function	Purpose	6 (20%)	4 (8,5%)
	Usability	6 (20%)	4 (8,5%)
	Fruition	1 (3,3%)	3 (6,3%)
		13 (43,3%)	**11 (23,4%)**
Total		**30**	**47**
Duration of interaction		22:00:00	

Number of events		18	24

Fluency

Both Gary and Alice focus heavily on a combination of *materialization* and *function* (86,6% for the latter and 85,1% for the former). *Human factors* are, as was observed in other interactions, absent from Alice's events.

The diagram (figure 8) shows that while Alice's focus was heavily placed on materialization and function, her DG references are articulated with each other.
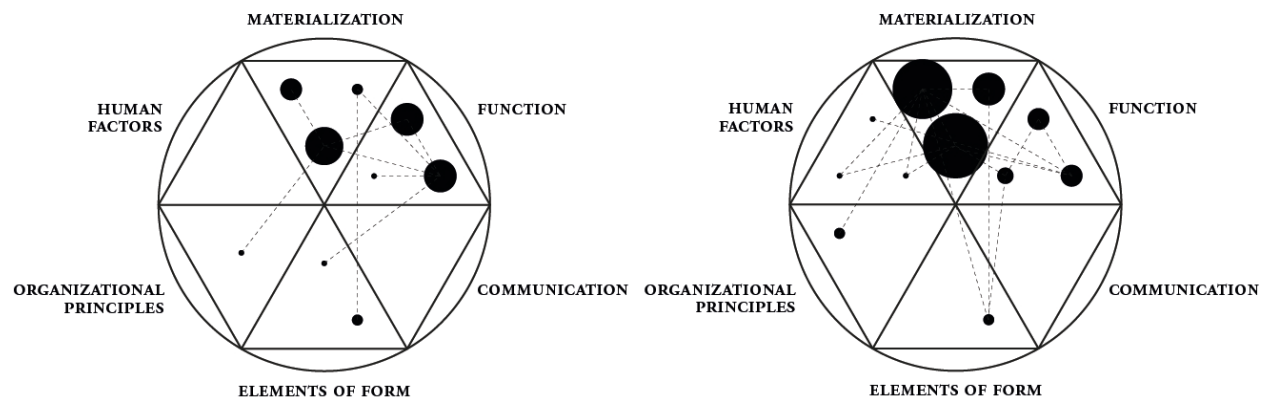

Figure 8. Diagrams of Alice (left) and Gary's (right) interaction

Mediation

Comparing both diagrams we can observe that the teacher tried to include *human factors* into the interaction, but in general, focused on the same issues as Alice, with a very clear emphasis on *materialization*.

Where with Adam (interaction 3) and to a lesser extent with Lynn (interaction 1) the teacher's overall diagram illustrated a certain complementary nature to his approach, here Gary's diagram is a sort of amplified mirror of Alice's.

Interaction 5: Sheryl, 2nd review

Interaction 5: Sheryl, 2nd review

The first 5 minutes of this interaction are missing. This could help explain the short number of events registered for Sheryl (4), however, it is worth noting we identified 13 events for the teacher. This interaction is very short (5.46 minutes).

Table 13. DG Sheryl – 2nd review

		Sheryl	Gary
Elements of form	Form generators	0	0
	Attributes of form	0	3 (10,3%)
		0	**3 (10,3%)**

Organizational principles	Composition and visual organization	0	0
	Spatial organization	0	0
	Structure of visual relationships	0	0
		0	**1 (3,4%)***
Communication	Semiotics	0	1 (3,4%)
	Communication process	0	0
		0	**1 (3,4%)**
Human factors	User requirements	0	0
	Ergonomics	0	1 (3,4%)
	Economic factors	0	1 (3,4%)
		0	**2 (6,8%)**
Materialization	Materials	3 (60%)	10 (34,4%)
	Structure	0	4 (13,7%)
	Configuration	1 (20%)	6 (20,6 %)
		4 (80%)	**20 (68,9%)**
Function	Purpose	0	0
	Usability	1 (20%)	2 (6,8%)
	Fruition	0	0
		1 (20%)	**2 (6,8%)**
Total		**5**	**29**
Duration of interaction		05:46:00	
Number of events		4	13

Fluency

Sheryl's frequency and variety of DG elements are obviously very low. The focus is almost exclusively placed on *materialization* issues (80%).
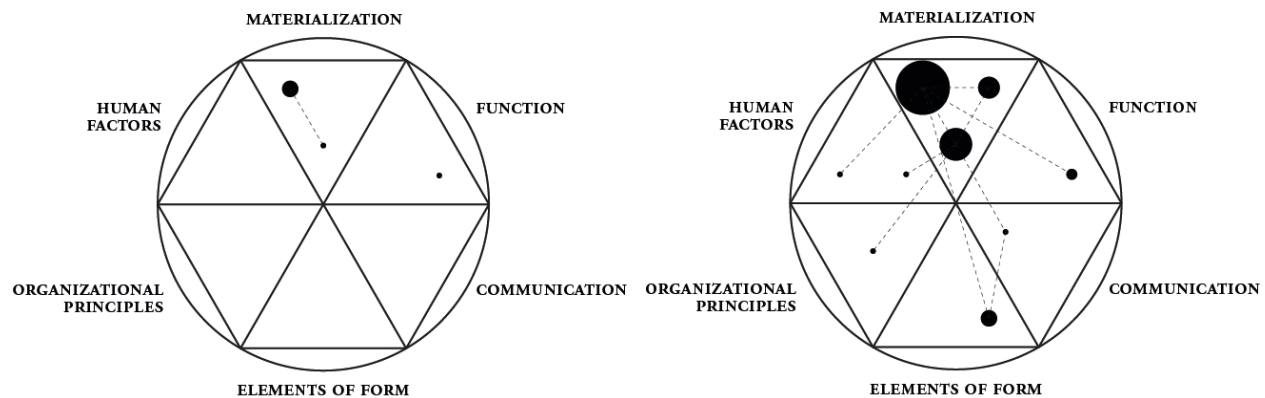
Figure 9. Diagrams of Sheryl (left) and Gary's (right) interaction

Mediation

In this case, the diagram merely reinforces the obvious low frequency of DG elements, and quite naturally, there are not many articulations between them. The teacher's diagram does not suggest any particular pattern, it is very similar to the ones we observed in other interactions – overall broader in scope, with more articulations and variety of DG elements.

It is worth noting that the 4 events we identified for Sheryl occur within the first 50 seconds of interaction. This reveals a unidirectional dialogue clearly driven by the teacher.

We did not find any particularity in the diagrams or in the transcripts, regarding the teacher's overall approach. Unlike Adam's interaction (interaction 3), for instance, where it was clear that Gary had a different performance (more complementary with the student's). This will be discussed further during the discussions part of this paper.

Look-like interactions (overview analysis)

The look-like interactions correspond to a stage of the project when the students are working on their models. At this point, crucial decisions regarding the overall direction of their projects have already been made. Therefore, these interactions focus heavily on model-making details (what kind of materials to get, how to put them together, and so on) and presentation issues. Furthermore, the interactions are much shorter and the DG content scarce.

The interactions were closer to the 10 minute mark (Addison 11.09; Esther 12.00 and Todd 8.58) with the exception of Sheryl's which registered 22.25 minutes. We will look into Sheryl's interaction with more detail further ahead, and address the remaining three interactions as a whole.

As was stated, the interactions where very short and concentrated heavily on materialization issues, Esther and Addison registered 66,6% and 62,5% respectfully, while Todd referred to materialization on <u>all</u> of his identified 7 events (100%). The total number of events was also lower than in the previous two stages, with Addison registering 8, Esther 12 and Todd only 7. It is worth noticing that at this stage the meetings occurred while the students worked with a computer assisted design software.

Interaction 8: Sheryl, Look-like review

Sheryl's interaction during the look-like review was not consistent with the pattern described above. The analysis of her previous interaction (see interaction 5) also suggested a less developed fluency in DG, as such we decided to look into her look-like interaction as well.

The meeting lasted much longer (22.25 minutes) than the other three look-like reviews. We identified 12 events for Sheryl and 18 for Gary. The split widens regarding the categorizations with Gary registering 27 and Sheryl only 12.

Regarding DG categorization the interaction followed the previous observations closely, with *materialization* having the majority of references (50% for Sheryl and 62,9% for Gary), however, Sheryl's score is lower than the other students (66,6%, 62,5% and 100%) this could suggest that she might still be unsure about which direction to follow.

Table 14. DG Sheryl – Look like review

		Sheryl	Gary
Elements of form	Form generators	0	0
	Attributes of form	0	2 (7,4%)
		0	**2 (7,4%)**
Organizational principles	Composition and visual organization	1 (8,3%)	3 (11,1%)
	Spatial organization	0	1 (3,7%)
	Structure of visual relationships	0	0
		1 (8,3%)	**4 (14,8%)**
Communication	Semiotics	0	0
	Communication process	0	0
		0	**0**
Human factors	User requirements	0	0
	Ergonomics	0	0
	Economic factors	1 (8,3%)	0
		1 (8,3%)	**0**
Materialization	Materials	2 (16,6%)	6 (22,2%)
	Structure	3 (25%)	7 (25,9%)
	Configuration	1 (8,3%)	4 (14,8%)
		6 (50%)	**17 (62,9%)**
Function	Purpose	0	2 (7,4%)
	Usability	4 (33,3%)	2 (7,4%)
	Fruition	0	0
		4 (33,3%)	**4 (14,8%)**

Total		12	27
Duration of interaction		22:25:00	
Number of events		12	18

Fluency

Of all 9 interactions observed, this was the only occasion when the number of events equaled the number of categorizations; i.e., in every event Sheryl referred to only one, non-articulated, element of DG. Below we can see three transcripts that illustrate Sheryl's overall interaction:

"I mean I could just make it out of wood, couldn't I? Just like (...) cut a piece of wood?"

"And then my other concern – yeah, I wanted it to be symmetrical kind of similar."

"Um, and then this would be metal."

The DG elements are referred to separately, that is, disconnected from their effects to the whole, and without articulating the various DG elements with each other. This is illustrated clearly in the diagrams bellow (Figure 10)
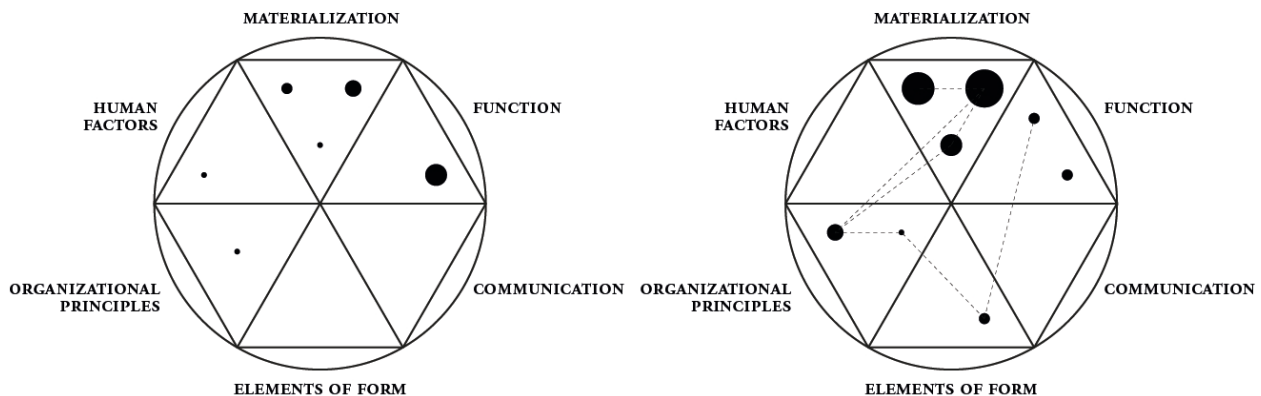

Figure 10. Diagrams of Sheryl (left) and Gary's (right) interaction

In Figure 10 we can observe that Sheryl is still exploring several DG elements. There is a focus on *function* and *materialization*, but what stands out is the inarticulate nature of her DG elements.

Mediation

It seems relevant to observe that of the 18 events we identified for the teacher, 12 corresponded to isolated references of DG elements. Below we can see (table 15) a fragment of the interaction between 3.00 and 7.23 minutes. The conversation progresses in a balanced dialogue, without either of the participants dominating the interaction. However, we can notice both Sheryl and Gary exhibit the same fragmented approach, that is, they refer to DG elements without articulating them with the whole or between the parts.

Table 15. Sheryl, look-like review, analysis table (fragment)

Student *Sheryl*	**2.** *03.00*	And then in the middle, these telescope, so you can raise and lower the table height.		- Usability (F2)
Teacher *Gary*	**2.** *03.10*	How is that gonna work – just push, pull?		- Structure (M2)
Student *Sheryl*	**3.** *03.17*	Okay. 'Cause I have some ideas, but I'm not – like I thought of telescopic, uh telescopic. But, um, the – there's like a physical lever thing and you just close it. 'Cause I'm gonna model that into it.		- Structure (M2)
Teacher *Gary*	**3.** *03.29*	So where would the lever be?		- Structure (M2)
Student *Sheryl*	**4.** *03.30*	Just in here. 'Cause you – I mean to lift it, you have to pull the seats out		- Usability (F2)
Teacher *Gary*	**4.** *03.37*	You gotta be something just where you could push down and, and turn and locks kind of thing.		- Usability (F2)
Teacher *Gary*	**5.** *03.49*	So you're, you're gonna make eight pieces then, right?		- Purpose (F1)
Student *Sheryl*	**5.** *03.51*	Um, I think so. Because you could have two on each side.		- Usability (F2)
Teacher *Gary*	**6.** *03.54*	I mean so you – that means so you all, so you'll be able to have a full ah assembly all under in there? (...) Or all eight of 'em?		- Usability (F2)
Teacher *Gary*	**7.** *05.44*	Then your – what material for your top?		- Materials (M1)
Teacher *Gary*	**8.** *05.48*	you can have, ah, 'cause they have some really interesting high-pressure laminates, ah, on all the wood veneers (...) Or – I mean there's a really – there are some cool, ah, it was handmade high-pressure laminates from Italy that I spec'd once ah on boat interior cabinets.		- Materials (M1)
Student *Sheryl*	**6.** *06.20*	I mean I could just make it out of wood, couldn't I? Just like (...) cut a piece of wood?		- Materials (M1)
Teacher *Gary*	**9.** *06.29*	How big's your tub?		- Configuration (M3)
Student *Sheryl*	**7.** *06.30*	Two inches, so it's two thick. (...) So that would be kinda thick.		- Configuration (M3)
Teacher *Gary*	**10.** *06.31*	And they like the two inch dimension, so you'd – you'd probably gonna go an inch and a half, inch and a half with a, a, half-inch space around it, you know, just to laminate it up to your two inches. Um, you can – ah, there's a – there is some places. I can show you some really trick ways how to put on literally iron on a veneer.		- Configuration (M3) - Materials (M1)
Teacher	**11.**	Sheryl, underneath when you take those		- Materials (M1)

Gary	07.08	out, what's, what's the surface of the bottom piece? Is it identical to the top?		
Student Sheryl	**8.** 07.14	And then my other concern – yeah, I wanted it to be symmetrical kind of similar.		- Composition and visual organization (O1)
Teacher Gary	**12.** 07.18	So that'll be wood, wood veneer on the underside.		- Materials (M1)
Student Sheryl	**9.** 07.23	Um, obviously, this pole would need a little something to attach it to the table. Um, I don't have that yet, but just like I don't know what it's called. You know what I'm talking about, though?		- Structure (M2)

In these transcripts both participants seem to mirror each other's approach. This fragmented approach is not representative of the teacher's overall pattern observed during the study. At this point, we would like to raise the hypothesis that the teacher's approach varies according to the student at hand, which is understandable and even expected. However, in this case, the teacher's performance (in terms of DG fluency) was lower than before. We have no way to establish, in this study, if this was a deliberate or even strategic approach by the teacher, or if it was a consequence of the natural dynamics of human interaction. We shall discuss this issue further in the discussion section of this paper.

5. Discussion

5.1 Making connections

There were many different approaches to analyze the DTRS dataset. Yet, most studies reinforced the notion that teacher-student interactions in a design-studio setting (sometimes referred to as design crits, design reviews, desk reviews, design critiques, etc; all of which have the same common denominator of a one-on-one dialogue between teacher and student in a design-studio setting) remains the fundamental moment for Design Education. Regardless of what particular approach, framework, or theoretical lens was used, the design reviews were shown to be a particularly rich area of inquiry.

The different approaches were reflected on the seven different symposium sessions. However, similar issues emerged not only in same-topic sessions but also across sessions which lead to highly insightful discussions. This was reinforced by the final day's workshop that presented the opportunity to further explore issues and themes which emerged during the symposium.

Before moving on to the discussion of our study's results, we would like to highlight a couple of issues which connect specifically to our study. In common with our approach, several studies focused on making design knowledge more visible. The approaches varied from focusing on a pedagogical angle to a focus on a more professional, design-skill knowledge angle. A clear example of the former was Adams, et. al (2014) paper that focused on "(...) the content-specific specialized teacher knowledge that gets at the how and what of teaching design." (p.1); while, for example, D'Souza's (2014) paper stands as perfect example of the latter.

It is interesting to reflect on this issue in the following manner: design education, and design reviews in particular, are based on project-based learning, a setting in which the students learn-

by-doing while being tutored by a teacher. In this context, the skills and experience of the teacher as a professional designer are an important part of what is being taught. That is, the professional design skills *are*, at least in part, the pedagogical content being taught. Of course, what is the most effective way of bridging the gap between unexperienced student and teacher is a question that still needs answering, specific pedagogical strategies might be needed to frame the specific design-skill content transmitted to the student.

This issue was partly addressed by McDonnel (2014) in which the author suggests that Gary's (the instructor of the ID-junior students) performance exhibited a perfect blend of professional expertise and pedagogical know-how.

"Close examination of how Gary instructs his students shows us a highly skilled, nuanced set of activities which help to demystify how 'knowing how' is nurtured through careful navigation between modes of instruction using a rich variety of conversational strategies." (McDonnel, p.22)

Another common issue during the symposium was the focus on trying to make the content of the design reviews visible. The approaches varied, with some authors for example Scheer, et. al (2014) and Sonalkar, et. al (2014) focusing clearly on finding ways to explicit verbal discourse, while, for example, Tenenberg, et. al (2014) proposed an inquire into gestures and stances.

5.2 Discussion

Our study proposed to use the Design Grammar Model (DGM) as a framework to analyze teacher and student interactions. This approach allowed us to make the *content* of these interactions more visible. As a result, we were able to analyze and compare the design grammar knowledge (*fluency*) of teacher and students.

The criteria to evaluate *fluency* in design grammar was: *frequency* of reference to DG elements, *variety* of references, and *articulation* of DG elements. A pattern that emerged from this was that the teacher, not surprisingly, consistently registered higher on the frequency of references to DG elements, the teacher displayed also, in general, a broader approach to DG (specially in the 1st and 2nd review) that is, whereas most students focused clearly on one or two areas of DG, the teacher had a more balanced and holistic approach.

Our study also lead us to the following insight: when interacting with students with less design grammar knowledge the teacher's performance was poorer and, consequently, the quality of the interactions lowered.

This insight seems somewhat counter-intuitive, it would be expected that a teacher would try to bridge the gap with the student, that is, to bring him or her closer to his level and not the other way around. However, in this study, the richer interactions were observed during meetings with the students portraying higher design grammar *fluency* (see interaction 3 with Adam and, to a lesser extent, interaction 1 with Lynn). It is not possible, in the context of this study alone, to understand the reasons behind this insight. However, we assume that the nature of the design-studio pedagogical setting could partly explain it; i.e., as was stated in the theoretical framework, the learning-by-doing pedagogical context is not without its pitfalls, tutorial-learning heavily depends on the largely unpredictable dynamics of personal human interaction. We have no way to assert if the teacher was adapting his performance strategically, or if it was a consequence of the natural dynamics that emerge when dealing with different students, or even perhaps a case of

the teacher adapting his expectations according to his perception of the student's quality (Cotton, 1989).

The previous observation might open the discussion regarding the teacher's overall strategy when dealing with students in different stages of DG development. In order to investigate this issue, future studies will have to follow the same students during a higher number of interactions. Furthermore, it could be worthwhile to work closely with the teacher being observed in order to experiment with different teaching strategies during personal interactions.

Also resulting from this study is the observation that earlier stages of the design process are richer in terms of DG frequency and variety of events. There was a very clear difference between the first and second review and the look-like review in terms of content. The first two reviews resulted in a wide scope of elements of Design Grammar being addressed, from basic design grammar to materialization issues, function, and so on; whereas the 'look-like review' was clearly focused on materialization issues, and mostly concerned model-making. This comes as no surprise, since it is consistent with several studies which demonstrated that the early stages of project development are highly unstable, and a higher number of possibilities are still open for exploration. As such, subsequent studies should focus heavily on the early stages of project development, without, of course, compromising the overall monitoring of the process until the end.

Acknowledgements

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Biographies

João Ferreira is a free-lance graphic designer and PhD candidate at TU Delft. He holds a Master of Communication Design from the Faculty of Architecture of the University of Lisbon (FA.UL) and a bachelor of Product Design from the same University.

Professor Henri Christiaans holds a M.Sc in psychology and a PhD in industrial design engineering. His current position is associate professor at Delft University of Technology, School of Industrial design Engineering, and invited professor at the faculties of Architecture and Design of Universidade do Minho, and Universidade de Lisboa in Portugal.

Rita Almendra is a Designer and Professor at the Department of Design, Faculty of Architecture, University of Lisbon. She is the Vice-President of the Pedagogical Council at FA.UL. She holds a PhD in Design, a Master on Design Management and an MBA with marketing specialization.