Diagnostics for Design Thinking Teams

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Abstract Multidisciplinary teamwork is a key requirement in the design thinking approach to innovation. The tools currently available for effective team coaching are limited to heuristics derived from either experienced design thinking professionals or clinical psychology practitioners. Our research aims to improve this current situation by providing design thinking managers, coaches and instructors a scientifically validated tool for augmenting design team performance. We present the development of a software tool called the IDN Tool based on the Interaction Dynamics Notation to analyze team interactions and diagnose patterns of behavior that influence design outcomes. We demonstrate the use of the IDN Tool through analysis of the interaction behaviors of seven design teams engaged in a concept generation activity, which were independently rated by a two-person Jury using the criteria of utility and novelty. Through the analysis we were able to visually isolate the interaction behaviors that had a high positive or negative correlation with the levels of novelty and utility of concepts judged a priori. With further work, this has the potential of improving in-process design team performance with a positive influence on design outcomes.

1 Introduction

Design Thinking as an approach to the development of new products or services emphasizes three key elements—user empathy,[1] iterative prototyping,[2] and multidisciplinary teamwork. Individuals from different disciplines, departments, and

[1] User empathy and perspective-taking.

[2] Ideation, prototyping, and testing.

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different stakeholder groups participating in a design thinking project work in teams to understand user needs, develop product concepts, prototype and test concepts with users to come to a product outcome that meets user needs. Teamwork thus underlies all the activities that comprise design thinking projects. However, this crucial element of teamwork is neither well understood nor appropriately supported in practice. In industry and academia, design managers and instructors often put individuals into teams and take them through the various activities of design thinking with only little understanding about characteristics that make a design team effective. The tools for teamwork coaching are limited to heuristics derived from either experienced design thinking professionals or clinical psychology practitioners.

On the other hand, design-thinking research has investigated teamwork since 1990s (Tang and Leifer 1991; Cross et al. 1996; Valkenburg 2000). But this research has not had any significant impact on design thinking practice. Even now, recent research findings about affect expression (Jung 2011), team composition (Schar 2011; Kress 2012), and idea generation in teams (Edelman 2011) do not influence the practice of design thinking in industry or academia. This situation reflects a knowing-doing gap (Pfeffer and Sutton 2013) between research and practice.

How do we overcome the knowing-doing gap between research and practice? We propose that ***the understanding of teamwork emerging from research studies needs to be embedded in diagnostic instruments that are useful to practitioners***. The development of instrumentation has been a key factor in the development of medicine as a science based practice. Instrumentation for diagnosis and intervention has enabled scientific discoveries to be available at hand for medical practitioners to use in the messy real-world situations that confront them. In a similar vein, we propose that design research needs to develop instrumentation for diagnosis and intervention that enables research discoveries to be amenable for practical application. In this chapter, we present the development of a diagnostic system for design teams that integrates research findings about team behavior in a visual form that is amenable for application to practice.

2 Research Questions

The questions guiding our research in the development of a visual diagnostic system for design thinking teams were as follows.

1. What is the spectrum (or atlas) of discernable and significant interaction patterns that occur in design thinking teams?
2. How do these interaction patterns influence design outcomes?

A diagnostic instruments needs to not only detect patterns but also indicate what the patterns signify in terms of design outcomes. Question 1 refers to the identification of interaction patterns in design teams. Question 2 refers to the significance of the identified patterns in terms of influence on design outcomes. The following section describes the method followed to investigate these questions.

3 Method

We adopted an engineering design approach to develop and test a visual diagnostic instrument. Our prior research (Sonalkar 2012; Sonalkar et al. 2013) had led to the development and validation of the Interaction Dynamics Notation. The notation had shown that through effective use of a visual symbol system, it was possible to integrate previous research on team dynamics into a single analysis system while retaining the moment-to-moment temporality of team interaction. The Interaction Dynamics Notation was chosen as the foundation on which to build a visual diagnostic instrument for design thinking teams. An overview of the Interaction Dynamics Notation is given in Sect. 4.

Once the Interaction Dynamics Notation was chosen to build the visual diagnostic instrument, further design requirements for such an instrument were identified and multiple prototypes were built to satisfy these requirements. These were iteratively improved through testing on a databank of videos of teams engaged in concept generation activity. This resulted in the development of the IDN Tool. The development of the IDN Tool is discussed further in Sect. 5. Section 6 describes the specifications of the IDN Tool.

The capability of the IDN Tool as a diagnostic instrument was tested with a dataset consisting of concept generation interactions of seven teams. The concepts generated by the teams were analyzed in terms of their novelty and utility to generate outcome measures. The patterns identified through the IDN Tool were correlated to the outcome measures to identify the interaction patterns that could have an influence on design outcomes. Sects. 7 and 8 describe the application of the IDN Tool to concept generation interactions and the detection of interaction patterns correlating with design outcomes.

4 Interaction Dynamics Notation: An Overview

Interaction Dynamics Notation creates a descriptive visual model of team interaction by interpreting and assigning symbols to observable speaker expressions (verbal and nonverbal). The assignment of symbols is conducted based not on what the expression is from the point of view of the person making it, but on what the expression is taken to be and responded to by others in the team. So in effect we are modeling a series of speaker responses rather than a series of speaker expressions. Thus, the Interaction Dynamics Notation is a visual model of an unfolding interaction. Figure 1 shows the Interaction Dynamics Notation of a brief design conversation.

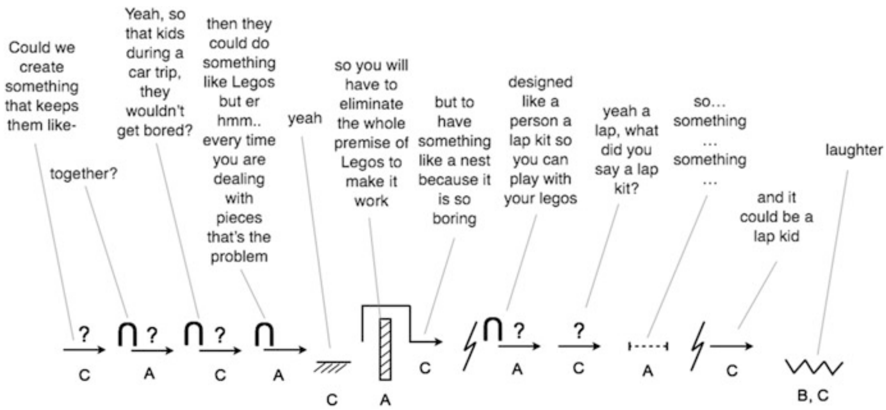


Fig. 1 A conversation between three designers A, B and C is visualized using the Interaction Dynamics Notation

Table 1 gives a detailed explanation of each symbol used in the visual notation. For further information about the development of the Interaction Dynamics Notation, please refer to Sonalkar et al. (2013).

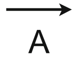
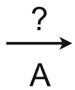
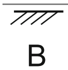
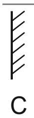
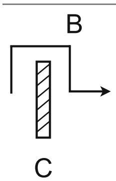
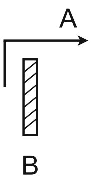
5 Development of the IDN Tool

The initial research on the Interaction Dynamics Notation depended on paper and pen based manual analysis of video. This was a tedious and time-consuming process. In order to use the Interaction Dynamics Notation in a visual diagnostic instrument viable for real-world use, it was necessary to develop a software tool that would accelerate the use of the notation. This software tool would then form the core element of a visual diagnostic system for design thinking teams. The following design requirements were identified for developing this software tool, which later became known as the IDN Tool.

5.1 Functional Requirements

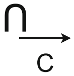
1. The IDN Tool must work with video data as well as conversations happening in real-time.
2. The IDN Tool must give a visual output in terms of the Interaction Dynamics Notation that is easy to understand.
3. The IDN Tool should include sequential analysis methods in order to accelerate the analysis of team interaction patterns.
4. The IDN Tool must work on both Windows and OSX platforms.

Table 1 The visual symbol set for the Interaction Dynamics Notation

Symbols	Name	Description	Example
	Move	A 'move' indicates that a speaker has made an expression that moves the interaction forward in a given direction.	A: I need to buy Legos (at) home. Think about how therapeutic it would be.
	Question	A question indicates an expression that elicits a move. A question projects onto the next response and constrains the content of that response because the next response needs to answer the question.	A: Where should we start?
	Silence	Silence is a state in the conversation when none of the participants speak as they are engaged in other individual level activities. Silence has been included in the notation as a number of design conversations are an interplay of both group conversation and individual activity.	
	Block	Block indicates an obstruction to the content of the previous move. For a block to be felt, the coder needs to feel that the response in some ways obstructed the flow that was established by prior moves.	B: Maybe have something which looks like a computer but you can just type your name or do a simple math, a calculator in the shape of a computer kind of. C: Er, but I don't know, I mean, considering the age segment we are targeting 3–7 years.
	Support for move	Support-for-move indicates that the speaker understands and/or agrees with the previous move.	C: Safe and entertaining (bending forward to write). B: Safe and entertaining, yes.
	Support for block	Support indicates an acceptance of a block by another person.	A: But that's also, I think that's already done. C: Yeah, its already there. B: Ok.
	Overcoming	Overcoming a block indicates that though a block was placed in front of a move, a speaker was able to overcome the block and persist on course of the original move.	C: Er, but I don't know, I mean, considering the age segment we are targeting 3–7 years. B: So 7 years they go to school, they would learn A, B, C right?
	Deflection	When a speaker blocks a previous speaker's move, that speaker or another can deflect the block with a move that presents an alternative direction for the interaction.	B: So when you say we need to divide the age-group, but you cannot have like 3, 4, 5. A: No, no of course not, but I mean you might have a few different (concepts).

(continued)

Table 1 (continued)

Symbols	Name	Description	Example
	Interruption	An interruption is indicative of a speaker being interrupted by another speaker or at times by himself.	B: Should we start generating some concepts now? A: Yeah (interrupted by X). X: 10 min are gone.
	Yes and	A move is considered to be a 'Yes and' to the previous move if it accepts the content of the previous move and adds on to it.	A: What about... if we made a toy that incorporates girls and boys. Its like a house that has a car with it kind of like enables the guys to play with the girls? C: I think that's a good point to have some sort of a educational point in it.
	Deviation	Deviation indicates a move that changes the direction of the conversation from the one implied by the previous moves.	C: But we need to remember it. C: This is not the buildable room (deviating from previous topic).
	Humor	Humor indicates instances of shared laughter in teams.	A: I don't know I probably would have swallowed but (All of them laugh).

5.2 User Interface Requirements

1. The user interface must be easy to use.
2. The user interface must accelerate the rate of video coding as compared to manual coding.

With these requirements in mind, the IDN Tool was developed through iterative prototyping with a set of test video data available from previous research studies (Sonalkar 2012). The following section describes the specification of the IDN Tool.

6 IDN Tool Specifications

6.1 Functional Specifications

The IDN Tool software enables a user, an IDN analyst or researcher to import video data, code the video data so that specific visual symbols are assigned to specific speaker responses, and then output this assignment of visual symbols as a visual representation. The IDN Tool also incorporates a sequential analysis functionality that includes finding patterns of sequential symbol assignments, and conducting a Markov analysis of the probability of one response following another. Figure 2 describes the basic functionality of the IDN Tool.

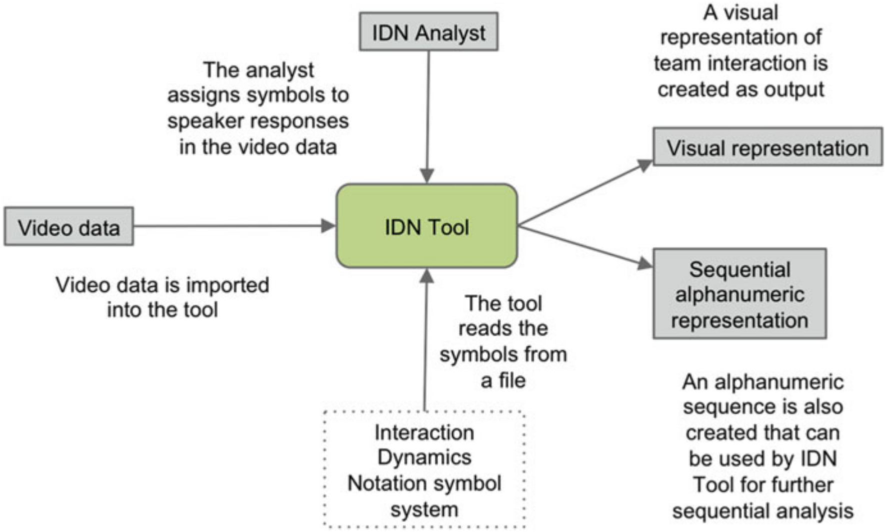


Fig. 2 Overview of the functionality of the IDN Tool

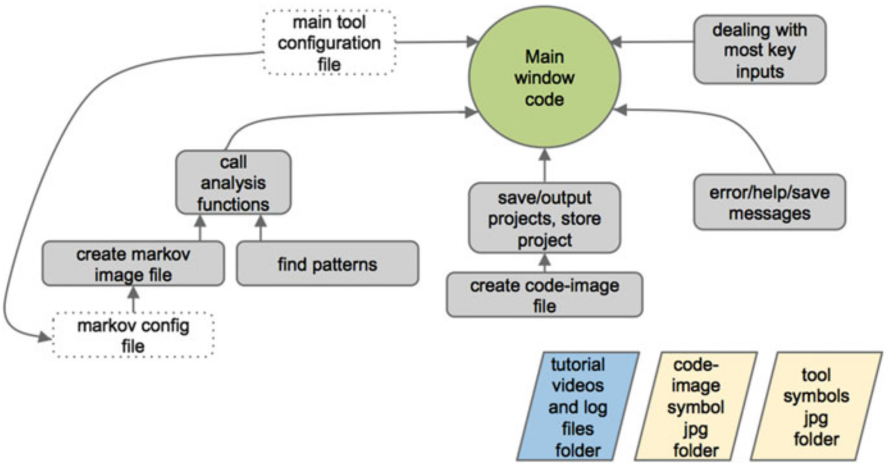


Fig. 3 Functional modules of the IDN Tool

This functionality is achieved through the various functional modules that are part of the IDN Tool as described in Fig. 3, and the file structure described in Fig. 4.

The IDN Tool is coded in Python language on a Linux platform. The decision of using Python on Linux was made in order to create a software code that could then be easily ported to Windows or mac OSX platforms.

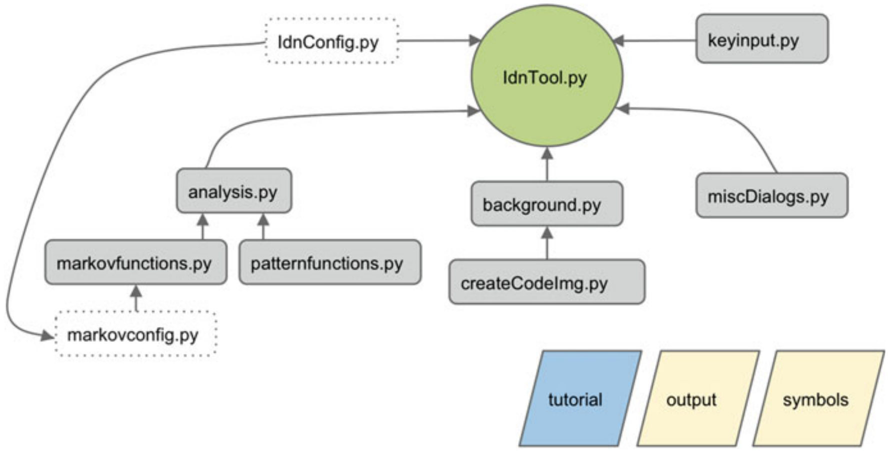


Fig. 4 The corresponding files architecture that forms the IDN code

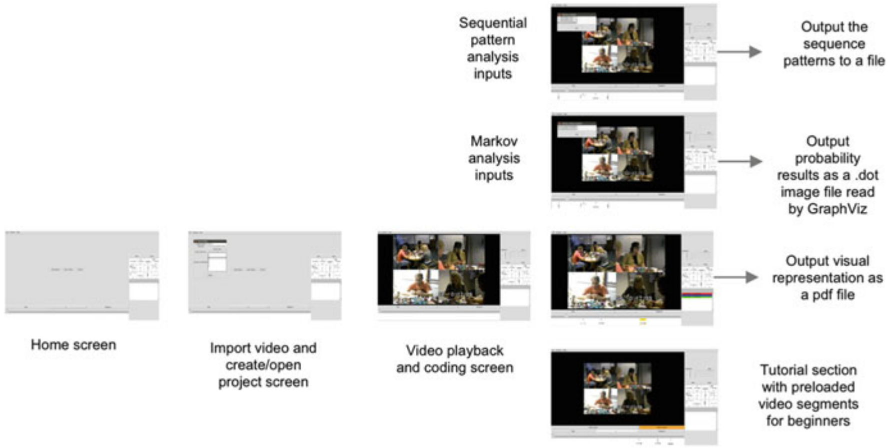


Fig. 5 Overview of the user interface screens of the IDN Tool

6.2 User Interface Specifications

Figure 5 describes the various screens that are part of the IDN Tool user interface.

The main video coding screen is shown in Fig. 6. The video is displayed prominently in the middle. The lower display bar shows the symbols that are being coded. The right-hand panel shows the speaker label assignments, and the hot key assignments for each symbol. It also includes a toggle button for coding start and stop of topic segments.

Fig. 6 The interface elements of the video coding screen of the IDN Tool

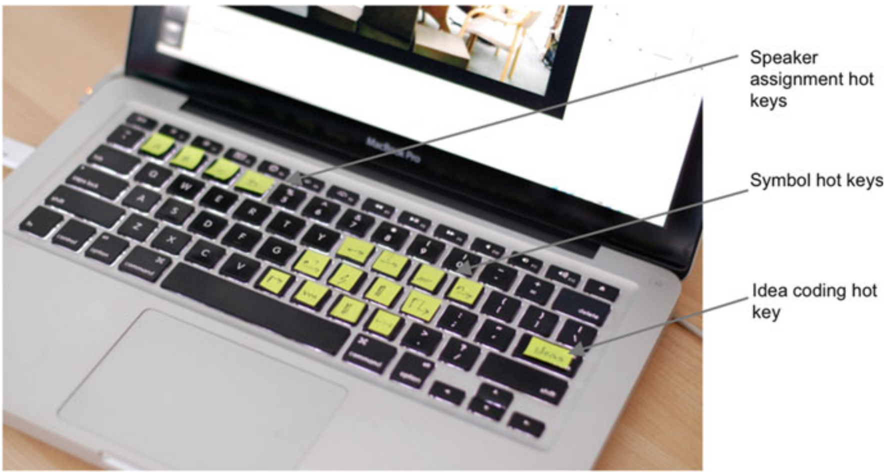


Fig. 7 Hot key labels on the keyboard to accelerate video coding

Once the coding is completed, the file can be saved and the visual output representation and the alphanumeric representation can be exported from the main menu bar.

In order to accelerate the coding of video, the IDN Tool can be operated through a set of hot keys. The keyboard is modified by overlaying the IDN symbols on the hot key buttons as shown in Fig. 7.

7 Analyzing Design Team Interactions with IDN Tool

Two team interaction analysis studies were conducted using the IDN Tool. The first was a comparative study of the IDN Tool with manual method of coding the Interaction Dynamics Notation. Four concept generation team sessions each of 40 min were analyzed using the IDN Tool as well as by using paper and pen. The comparison showed that the IDN Tool was 33 % more effective for researchers to code video data as compared to paper-based coding.

The second study was designed to test the version 3 of the IDN Tool with a data set that had measurable design outcome parameters. This study is described in detail in this section.

7.1 Concept Generation Study

Seven teams of three to four participants were given a concept generation task based on a real-world challenge. The participants were chosen from graduate students at Stanford University who had previous exposure to design thinking. The teams were invited in to the Design Observatory (Carrizosa et al. 2002; Törlind et al. 2009), which is pre-configured to record multiple video streams for design activity analysis. The teams were given the design brief that asked them to generate two concepts for the challenge of lifting water from below 50 ft. underground for small holding farmers in Myanmar. The design brief was designed to stimulate conversation and hence it explicitly asked the teams to generate a best-fit concept that would be technically feasible, and a wild idea or a dark horse concept that was unlikely to be feasible, but could revolutionize irrigation if it could work. The teams were given 60 min for concept generation and a further 20 min to sketch their deliverables and submit them to the research team. Figure 8 shows the team interaction setting and Fig. 9 shows a sample concept sketch arising from such team interaction.

The videos of the seven design teams were imported into the IDN Tool and analyzed to create visual representations of their concept generation interaction. The occurrence of ideas during interaction was depicted by highlighting the symbols corresponding to the speaker turns in which ideas were expressed. Figure 10 shows a sample visual representation output from the IDN Tool.

The use of IDN Tool for analyzing concept generation interactions of design teams demonstrated its use as a video coding tool. The IDN Tool generated a visual output, as well as an alphanumeric output of concept generation interactions for seven teams.

The IDN Tool used the alphanumeric output to detect sequences of symbols that occurred more than three times in the concept generation session. Some examples

Fig. 8 Four camera video stream of team design interaction

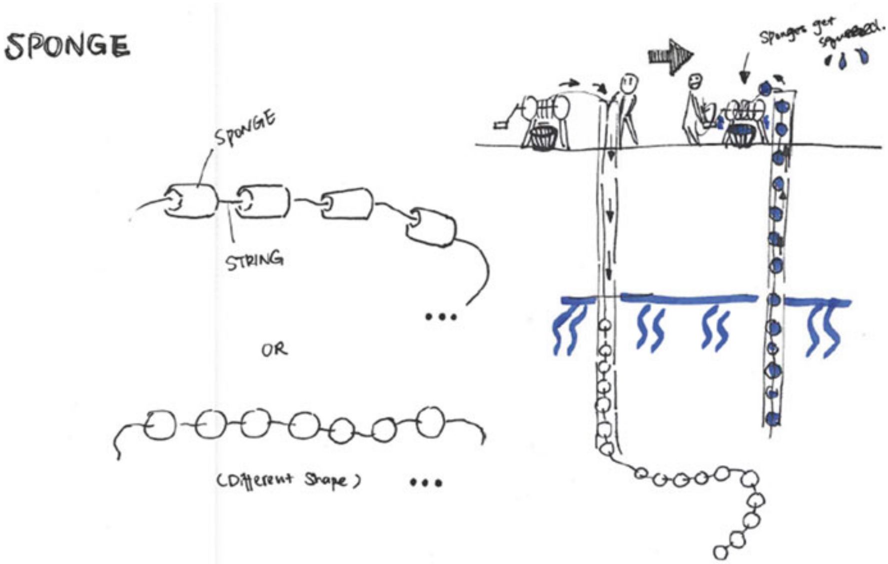


Fig. 9 A concept sketch developed by one of the design teams in the study

of sequences identified in Team 1 are mmqm (12 times), mshm (14 times), and mhms (eight times) where m = move, q = question, h = silence, and s = support. The IDN Tool was able to identify 33 (Team 7) to 142 (Team 2) such sequences in the concept generation data for each of the teams. The identification of such interaction patterns addressed the first research question presented in Sect. 2.

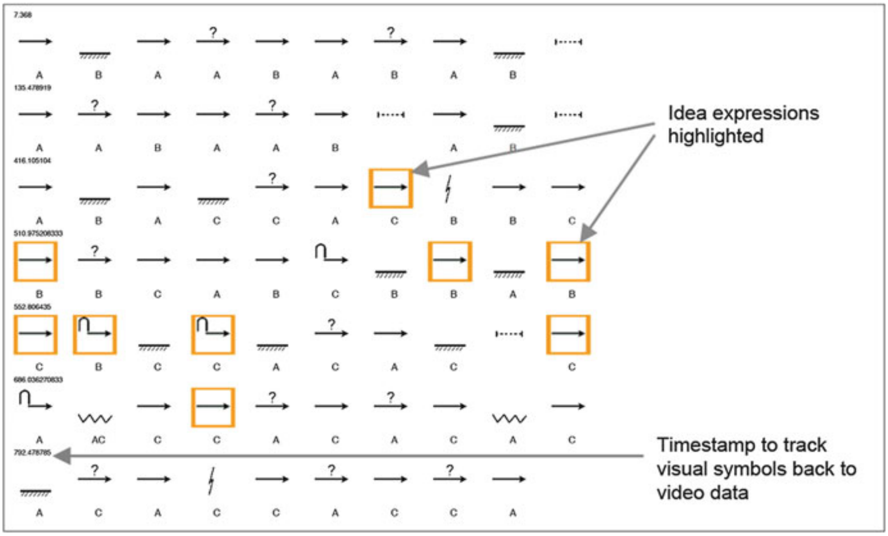


Fig. 10 A sample visual output of team concept generation interactions from the IDN Tool

However, even though these interaction patterns were identified, further analysis was required to address the second research question, and understand which of these patterns correlated with design outcomes.

7.2 *Expert Assessment*

In order to correlate interaction patterns with design outcomes, the concepts generated by the seven design teams were analyzed to obtain outcome measures. We used the ideation effectiveness metric proposed by Shah et al. (2003) to evaluate the concepts proposed by teams on their novelty and utility. The 14 concepts, two for each team were rated by two mechanical engineering experts on parameters pertaining to utility and novelty. Utility parameters included technical feasibility, satisfaction of requirements, manufacturability, serviceability and affordability. Novelty parameters included novelty of mechanism and novelty of human-machine interface. The ratings of the two experts were averaged for each of the 14 concepts. Since each team developed two concepts—one best fit and one dark horse, the team rating for utility and novelty was obtained by considering the utility score of the best fit concept and the novelty score of the dark horse concept. We followed this approach rather than doing an average of the score of two concepts, because the design task had explicitly called for developing two concepts one higher in utility and one higher in novelty. Table 2 lists the concept scores and team scores derived from the expert ratings.

Table 2 Concept scores and team score derived from expert ratings

Team	Concepts	Concept average utility score	Concept average novelty score	Team utility score	Team novelty score
Team 1	Tree mechanism pump (dark horse)	2.95	3.2	2.6	3.2
	Pressurized u-tube (best fit)	2.6	3.55		
Team 2	Continuous sponge tube (dark horse)	2.15	3.05	3.65	3.05
	Open mine well (best fit)	3.65	1		
Team 3	Capillary pump (dark horse)	2.25	3.1	2	3.1
	Continuous sponge tube (best fit)	2	3.05		
Team 4	Continuous belt of fabric (dark horse)	2.15	3.05	2.1	3.05
	Bamboo deep lift pump (best fit)	2.1	1.9		
Team 5	Handkerchief wringer (dark horse)	2.55	2.05	3.7	2.05
	Two sequential pumps (best fit)	3.7	1		
Team 6	Handpump + Archimedes screw (dark horse)	3.1	1.35	1.35	1.35
	Solar powered propeller pump (best fit)	1.35	2.65		
Team 7	Sponge chain (dark horse)	2.45	3.4	1.75	3.4
	Opposing piston pump (best fit)	1.75	2.5		

8 Detecting Interaction Patterns Correlated with Design Outcomes

The key interaction patterns identified through analysis of the visual output were then compared with the novelty and utility ratings for the seven teams. The comparison resulted in the following findings regarding the relationship between interaction patterns and outcome measures.

1. Episodes of concept elaboration had a strong positive correlation ($r = 0.71$) with utility. The greater the number of episodes of concept elaboration in a team, the greater the utility rating of the concepts generated by the team. Figure 11 gives an example of an episode of concept elaboration identified in the visual output of the IDN Tool.

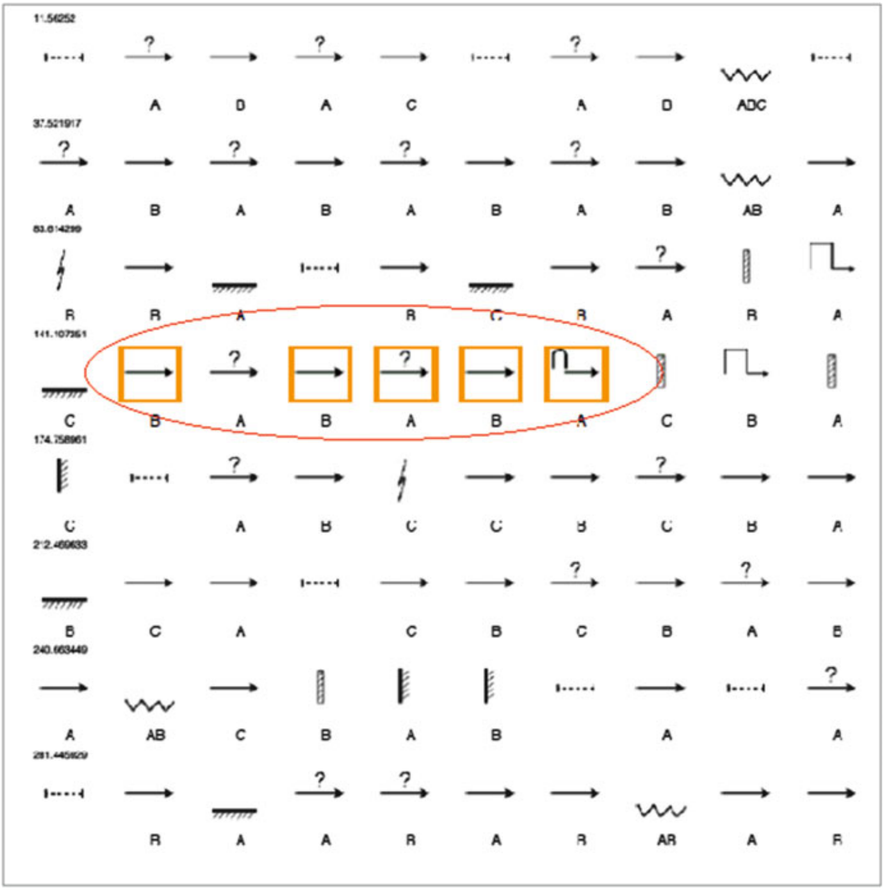


Fig. 11 This figure highlights an episode of concept elaboration. Concept elaboration episode consists of at least three consecutive idea expressions indicating that participants are contributing ideas to develop a particular solution concept

2. Dialectic episodes had a very strong positive correlation ($r = 0.9$) with utility. The greater the number of dialectic episodes in a team, the greater the utility rating of the concepts generated by the team. Figure 12 gives an example of a dialectic episode identified in the visual output of the IDN Tool.
3. Occurrence of humor had a strong positive correlation ($r = 0.55$) with utility. The greater the number of humor occurrences in a team, the greater the utility rating of the concepts generated by the team.
4. Occurrence of yes-and responses had a strong negative correlation ($r = -0.83$) with novelty. The greater the number of yes-and occurrences in a team, the lesser the novelty rating of the concepts generated by the team.

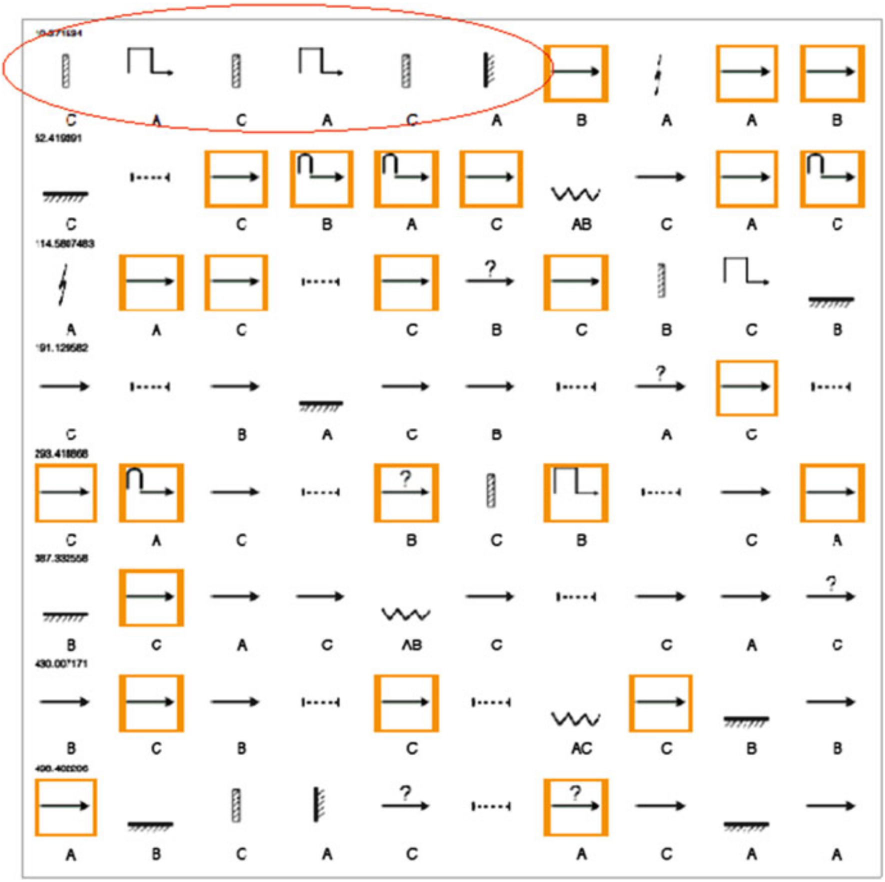


Fig. 12 This figure highlights a dialectic episode found within the visual output from the IDN Tool. A dialectic episode consists of more than two consecutive block and overcoming responses indicating that participants are engaged in an argumentative dialectic

5. Block-overcoming sequences had a moderate negative correlation ($r = -0.43$) with novelty. The greater the number of block-overcoming sequences in a team, the lesser the novelty rating of the concepts generated by the team.
6. Transitions between group work and individual work identified through occurrence of silence had a moderate positive correlation ($r = 0.34$) with novelty. The greater the number of transitions between group work and individual work in a team, the greater the novelty rating of the concepts generated by the team.

The identification of correlation between interaction patterns and design outcome measures shows how using the IDN Tool, we can detect interaction patterns that are positively or negatively associated with design outcomes. Further developments will be needed to calibrate IDN and improve its ease of use.

9 Limitations

A key limitation of the study is the small number of teams used to test the IDN Tool. Seven is a small number to obtain results that are statistically generalizable. Still, this preliminary study shows that it is possible to correlate the patterns identified through IDN Tool with design outcomes. Thus, the study can be considered significant not for its results, but for the process of establishing a protocol for testing a diagnostic instrument for design thinking teams: design activity—expert assessment of activity outcomes—pattern detection.

10 Discussion

Developing a visual diagnostic instrument for design thinking teams has implications for design thinking research, education and practice. A key element of a visual diagnostic instrument for team interaction is the reference database that indicates whether the pattern detected has any significant meaning in relation to the desired design outcome. Preparing such a database is itself a valuable research activity that could help develop a scientific foundation for our understanding of design thinking teamwork. In terms of instrumentation engineering, preparing such a database would correspond to calibrating the instrument. A key aspect of calibration with regards to design thinking is the identification and categorization of the context of the team interaction that is being analyzed. Since design is a context dependent activity, we believe that capturing the context in which team interactions occur is important in order to understand the limits of generalizability of patterns-outcome relationships. In the study of team interactions presented in this chapter, context parameters include the nature of the design activity—concept generation, the familiarity of the participants with each other—the team members were not familiar with each other before the study, and the familiarity of team members with the domain of the design brief—most participants were not familiar with the physics of water flow and pumping that formed the design challenge. We propose to repeat the study using the IDN Tool with a greater number of teams with varying context parameters in order to develop a robust calibration of relationships between interaction patterns and design outcomes mediated by the context of the design activity.

The key implication of a visual diagnostic instrument for practice and education is the capability to inform in-process feedback. Teams could be given behavioral feedback based on the visual diagnostic instrument that could enable them to improve their design performance. This feedback could be given either directly to teams or through coaches. The visual diagnostic instrument could become a coaching aid to inform coaches about on-going interaction patterns that could be conducive or detrimental to design outcomes, so that the coaches can then intervene appropriately. Thus, the development of a visual diagnostic instrument such as the IDN Tool discussed above has the potential to augment design team performance in education and practice, while being grounded in rigorous design thinking research.

11 Conclusion

In this chapter, we presented the development of a software tool called the IDN Tool that can help identify patterns of team interaction which are positively or negatively correlated with design outcomes. The IDN Tool was used to analyze concept generation interactions of seven teams. As we continue using the IDN Tool to analyze larger amounts of data, we expect to gradually build a database of team interaction patterns and their correlation with design outcomes. Such a database would form the reference database that would enable the IDN Tool to function as a diagnostic instrument for analysis of design thinking teams in industry and academia. The research presented in this chapter is the first step in that direction.

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