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Comparing the dialogue of experts and novices in interdisciplinary teams to inform design education

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Abstract

Design education has moved towards a collaborative practice where designers work in teams and with other disciplines to solve unstructured problems. Along with the cognitive skills involved in the execution of the design process, designers also need skills to work in teams, share information, negotiate common ground and reach consensus. Conversation is core to establishing successful collaborations and learning for students. In order to assess and facilitate collaboration skills, it will become necessary to understand what constitutes constructive and effective dialogue amongst students. The aim of this research is to compare expert versus novice interdisciplinary teams to understand how to better support teams to engage in constructive dialogue during educational design projects. Two cases were studied across different design domains during the problem definition, ideation and concept development phases of the design process. The cases involved a bio-medical fellowship project and an undergraduate product design project. The teams' conversations were recorded and qualitative content analysis was applied to reveal the cognitive processing and conversation activity that enabled the teams to progress during team collaborations. The findings show that during team interactions design teams alternate between four main cognitive processes, supported by a further six conversation activities to execute the design task. Experts were found to use these cognitive processes and conversation activities more effectively than novices. Recommendations are proposed that can guide design educators to support students during team interactions when solving design problems. The findings have implications for how team work is facilitated and assessed in education.

Keywords Experts versus novices · Educating design teams · Interdisciplinary teams · Cognitive processes · Dialogue of teams

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Introduction

Many problems in industry faced by designers are ill defined and require techniques beyond what is achievable by one discipline (Cross 2006; De Vere et al. 2010; Jonassen and Hung 2008). While interdisciplinary team work is common place in industry, it is less so in education where the curricular structure and requirement for assessment make it difficult to implement (Kiernan and Ledwith 2014). There has been some move to incorporate interdisciplinary education as a means to foster integrated design solutions (Kim et al. 2012; Nae 2017; Chou and Wong 2015) but there remains no clear approach as to how to conduct interdisciplinary teamwork (Chou and Wong 2015) or what pedagogic approaches may best benefit the student learning experience and how this can be evaluated (Self and Baek 2017). Assigning team projects does not mean that students will collaborate effectively (Bolton 1999) and tutors must instead be active facilitators of classroom-based teams to encourage productive dialogue (Lee 2014; Fredrick 2008).

Experts have been shown to have superior problem solving strategies in design (Björklund 2013; Lawson and Dorst 2013). Effective team cognition is about how well knowledge is mentally organised and distributed within a team and applied to approach problem solving, make assessments, judgements or decisions (Mol et al. 2015). In order to develop design expertise Garbuio et al. (2018), recommend the development of cognitive skills and the development and integration of domain knowledge (Mosely et al. 2018; Lawson and Dorst 2013). Kleinsmann et al. (2012) found that a differentiating factor between experts and novice design teams was the level of knowledge sharing and integration.

Chou and Wong (2015) advocate that interdisciplinary education must encourage dialogue to share knowledge and experience, push forward the boundaries of knowledge and solve problems with wider, multi-dimensional concepts to provide holistic solutions. However, the importance of dialogue has largely been ignored in education (Mercer and Littleton 2007). Studies on student discussions have shown that when students engage in discussion it is not necessarily productive (Ferreira and Lacerda dos Santos 2009) and they may only engage in high level discourse when they are prompted to do so (Jakobsson 2006). Examples of such studies are a framework developed by Xun and Land (2004) using question prompts to encourage peer interaction and a scaffolding discourse in design collaboration developed by Ferreira and Lacerda dos Santos (2009). Even when students engage in productive discourse they are usually unaware of how the dialogue was effective, making it difficult to transfer past productive strategies to maintain effective and efficient team work (Fredrick 2008). Therefore learning how experts apply cognitive skills through dialogue to progress in teams is the focus of this paper.

Cognitive processes in teams

The purpose of this section is to clarify how designers think when identifying and solving a problem. The cognitive processes used relate to four aspects of design practice: naming elements of the problem, framing the problem to form an interpretation, making a move towards a solution and reflecting on those moves (Cross 2004; Schön 1983; Dorst 2011). Whilst acknowledging that the processes discussed below are not the only processes they are central and therefore the focus of this paper.

Firstly, as design is solution orientated it has largely been associated with creative thinking. Creative thinking has been defined as the ability to think divergently and generate a large number of original ideas or solutions (Casakin et al. 2010; Goldschmidt and Tatsa 2005). It is associated with ideation and brainstorming (Runco and Jaeger 2012). The solution space in design can be large as designers iterate to come up with multiple solutions which provide many opportunities for creative thinking (Stempfle and Badke-Schaub 2002). Casakin et al. (2010) advocate that design education should assign high value to creative thinking as a measure of student performance and many studies in design have addressed levels of creative thinking as indicators of performance such as Badke Schaub et al. (2010) who categorised how ideas were generated to understand strategies that support innovation. Most tests of divergent or creative thinking look to fluency in generating a large number of diverse and original ideas (Paulus 2000; Runco and Acar 2012). For the purpose of this paper creative thinking is defined as:

Divergent thinking to explore and generate alternative ideas and options

Secondly, however while creative thinking is important in design it cannot alone address the scope of many of today's design problems. Design problems are considered to be complex, ill-defined (Jonassen 1997) and un-structured (Goel and Pirolli 1989). They involve conflicting goals, multiple solution methods, unanticipated problems, multiple forms of problem representation, distributed knowledge and constraints, to solve them (Jonassen 1997; Goel and Pirolli 1989). The design process also involves a series of stages that involve different objectives which may have a bearing on the type of thinking needed. The typical design process is split into three stages: the problem definition phase where the problem is understood, the development phase where ideation and concept development take place and the evaluation phase where the solution is tested (Jones 1992; Cross 2001).

While design has been associated with creative thinking, there is recognition that designing demands not only creative and divergent thinking, but also convergent thinking, which has not been extensively studied (Goldschmidt 2016). Dong (2007) describes how coherent design concepts come about through cycles of convergent and divergent thinking. Dorst and Cross (2001) describe design as a co-evolution process of developing and refining the problem and solution together, switching from the creation of the solution to further analysis of the problem. Convergent thinking is made up of logical deduction, analysis and evaluation. This is where convergent thinking must be used when creating solutions to disregard non-viable options with divergent thinking used once again to create further alternatives upon analysis (Ferreira and Lacerda dos Santos 2009; Stempfle and Badke-Schaub 2002; Dorst 2011). Critical thinking is convergent as it is logical, deductive thinking and involves actively questioning and analysing information to gain knowledge and determine specific answers (Choi and Lee 2009; Hung et al. 2008). It involves being able to evaluate a problem, make judgments and defend a position taken (Jonassen 2008). From a Delphi study Facione (1998) identified the following core critical thinking skills: analysis, inference, evaluation and interpretation. For the purpose of this paper critical thinking is defined as:

Convergent, logical and deductive thinking to interpret, analyse and judge information

Thirdly, Mol et al. (2015) define team cognition as "An emergent state that refers to the manner in which knowledge is mentally organised, represented and distributed within the team" (p. 243). Therefore effective communication is critical for design teams in creating and sharing design information, decision-making and coordinating design tasks to develop a shared understanding (Détienne et al. 2012; Chiu 2002). It has been shown that many teams fail to optimally use their distributed knowledge due to a poor understanding of each other, their task, and an overemphasis of agreement seeking at the expense of information elaboration (van Ginkel and van Knippenberg 2008). Therefore, communication and knowledge processing are key aspects of the collaboration process (Détienne et al. 2012; Mol et al. 2015). Knowledge processing refers to the co-construction of knowledge which is co-elaborated, appropriated and mutually accepted in collaborative problem-solving dialogues (Baker 2009). It includes turn taking and the co-ordination of communication processes such as asking for feedback and clarifications (ibid). For the purpose of this paper knowledge processing is defined as:

The process of elaborating, explaining, clarifying and exchanging information

Lastly, Schön's (1983) reflective practice theory proposes that design activities are based on actions and the ability to learn and make decisions from those actions. It involves a reflective conversation with the individual, the team and the problem situation where frames guide the design activity. Therefore in order to manage how they are thinking and strategising, teams must also apply metacognition. Meta-cognition (reflective thinking) is required to plan how to tackle the problem, monitor progress, and evaluate the appropriateness of the strategies used and the knowledge of the team to reach goals and develop solutions (van Ginkel et al. 2009; Jonassen 1997; Andres 2013). The main components of meta-cognitive regulation are: planning, monitoring and evaluating one's problem solving strategies (Flavell 1979; Schraw and Moshman 1995). For the purpose of this paper metacognition is defined as:

Self-reflection through planning, monitoring and evaluating oneself or the team

While the literature has addressed the cognitive processes of creative thinking, critical thinking, meta-cognition and knowledge processing there has not been reference in the literature to the application of the four processes together in design teams. By drawing together the literature on design and team cognition, indications are that all four are relevant to teams collaborating on design problems.

Experts and novices in design

A limited number of studies have addressed the conversation of experts versus novices in design teams. Design research has mainly focused on the processes of design students (Defazio 2008) or individual professional designers (Cross 2004) working on simplified tasks in controlled environments. Some comparison studies have been conducted (Björklund 2013) but have tended to focus on individuals rather than teams.

The work of Cross (1990) has been pivotal in assessing designers' ways to solve design problems. Earlier studies treated design as involving structured problems that could be broken down into well-defined sub problems to be solved linearly. Cross (1990) argued that designing is an iterative process to move back and forth between the problem and solution space as ideas uncover new problems and constraints. He illustrates how expert designers apply imagination, tolerate uncertainty and adopt solution-focused strategies as they develop solutions to ill-defined problems. Subsequent studies have confirmed these findings such as Cross (2004) and (Lawson and Dorst 2013). It was found that experts spend more time than novices qualitatively analysing, synthesising and defining or framing a problem (Jain and Sobek 2006; Atman et al. 2007). Christiaans (1992) found that the more time a designer spent on defining and understanding a problem the better able they were to achieve a creative solution. Experts therefore tend to view problems as more difficult (Cross 2004; Björklund 2013). By engaging in analysis more, experts display better critical thinking ability and are able to represent problems in multiple ways whereas novices are often restricted to a single form of problem representation (Jonassen 2003). Novice designers have a pattern of trial and error where experts plan several moves in advance, have a better capability of evaluating proposed solutions reducing the time to arrive at a final solution (Ahmed et al. 2003; Goldschmidt and Rodgers 2013). Experts have been found to be better at questioning data (Ahmed et al. 2003) and judging the relevancy of information and the relationship between chunks of information (Björklund 2013; Goldschmidt and Rodgers 2013). Haupt (2015) state that this due to experts relatively lose control systems, personal stopping rules and evaluation functions supporting them to go from a state of uncertainty to certainty.

Knowledge is also a differentiating factor between experts and novices. Experts have more domain knowledge and can apply this knowledge effectively while novices have limited ability to do so (Popovic 2003). One criticism of earlier theories are that they have ignored the context dependent nature of design problems (Smith 2015). Haupt (2015) argues that design is a process experienced within an environment which the designer encounters throughout the design task. This is supported by Björklund (2013) who found that experts also relied on deduced contextual information to solve problems. This highlights the need to study designers when working on real problems rather than prescribing well defined projects in controlled lab environments. Experts will also recall knowledge from previous projects and analogously apply this to a new project (Haupt 2015; Christensen and Ball 2016). Jain and Sobek (2006) question how novice designers can rely on experience that they do not yet have.

There is limited literature that has addressed design expertise in teams. Kleinsmann et al. (2012) advocate that there is a need to distinguish between what constitutes design expertise and collaboration skills when assessing design team performance. They found that the degree and quality of knowledge sharing and integration are differentiating factors between expert and novice design teams. Experts were found to be able to prioritise and share only relevant and goal related information while novices were found to only share knowledge at a shallow level without fully understanding the information. However their study looked only at knowledge exchange between teams which is only one aspect of team designing. They did not address other cognitive processing that must take place to solve design problems. Seidel and Fixson (2013) found that higher performing teams agreed better on the problem definition and had better team reflection, debating more over ideas and over the process to follow. Hong and Choi (2011) argue that this reflects good practice as teams that debate over and explore ideas tend to come up with novel innovations.

While the above literature has been instrumental in defining design expertise there has been criticism that these studies often don't reveal how novices can become experts (Smith 2015) and particularly within teams. While expertise in design can be summarised as the "possession of a body of knowledge and the creative and analytical ability to extract, analyse and apply this knowledge" (Popovic 2003), how this can be achieved has had limited study. Verbal material has been shown to reveal how designers think and as suggested by

Haupt (2015) can be used to assess cognitive performance. In order to support the dialogue of student teams it is necessary to understand the aspects of conversation that help teams to progress. Experts' processes have been shown to be superior to novices so it is also important to understand what constitutes expert conversation. Therefore the following research questions were used to guide the research:

1. What are the cognitive processes and conversation activities used by teams in addressing design problems?
2. What are the differences between experts and novices?

Method

Two qualitative case studies were carried out. The focus was to explore in detail small samples within a real-life context. (Yin 1994). Table 1 provides details of the cases and the data collected per phase of the design process.

The Undergraduate case: This case was selected as it involved two distributed undergraduate novice student teams from two different European countries. The first cohort were from a Product design and technology program while the second were from the disciplines of Industrial Engineering Management, Communication and Media Design and Product design and Engineering. Data was collected from a number of teams, and based on the final grades from the project, a team was selected from the lower (Undergraduate A) and upper (Undergraduate B) levels of the grades to provide balance. Due to recording difficulties it was not possible to capture a quality recording of Team A at the ideation phase and Team B at the concept development phase which may be a limitation of the study. The project was sponsored by a company who is a world market leader specializing in products and services for cabin interiors and aircraft systems. The design brief entailed the redesign of the crew rest to create an improved resting experience for long haul flight crew by understanding their unmet needs. The focus at each phase of the project was as follows:

- **Problem definition phase:** This involved uncovering and understanding the issues associated with the crew rest including the physical space along with the deeper emotional and physiological needs of flight attendants (FAs) from diverse social and cultural backgrounds.
- **Ideation phase:** This involved developing ideas around the needs and issues identified.
- **Concept development:** This involved developing a few select ideas in further detail and then finalizing on one solution. Table 2 describes the data.

The Med-Dev case: This case involved a fellowship program where trans-disciplinary teams follow an integrated design process to identify opportunities for innovations in the area of medical devices that reflect the needs of the users and stakeholders involved. The case explores a team at the post clinical immersion stage after spending 8 weeks in several hospitals carrying out ethnographic research to uncover needs in the area of gastroenterology. The participants could be described as experts as all had between three and over ten years professional experience with three holding postgraduate qualifications. They were from the disciplines of Biomedical engineering, Electronic engineering, Product design and Medicine. Only one team conducted this project and

Table 1 Case description

Case	Project	Data per stage in process	Expertise
Undergraduate case No of participants: 14 (2 teams of 7)	Design of a user-centred crew rest for flight attendants	**Problem definition:** Team A: 40 min Team B: 46 min. **Ideation:** Team B: 1h **Concept development:** Team A: 30 min	Undergraduate design students Novice
Med-Dev Medical device innovation. No of participants: 4 (1 team)	To uncover opportunities for innovation and design of a medical device	**Problem definition:** 3 h **Ideation:** 1 h 25 min **Concept development:** 50 min	Fellows Experienced /post-doctoral level

Table 2 Description of dataset for Undergraduate case

Description of data
Team A
Meeting 1: problem definition phase Duration: 40 min
Content: Audio and transcript of meeting between members of Team A
Present: Team A (4 cohort 1 participants only), 1 facilitator and 1 researcher
Units of Analysis: Topic segments: 13, utterances of Participants: 102
Meeting 2: Concept development phase Duration: 30 min
Content: Audio and transcript of meeting between members of team B
Present: Team A (all members), 1 facilitator and 1 researcher
Communication medium between distributed members: Skype
Units of Analysis: Topic segments: 15, utterances of Participants: 161
Team B
Meeting 1: problem definition phase Duration: 46 min
Content: Audio and transcript of meeting between members of Team B
Present: Team B (4 cohort 1 participants only), 1 facilitator and 1 researcher
Units of Analysis: Topic segments: 11, utterances of Participants: 134
Meeting 2: Ideation phase Duration: 1 h
Content: Audio and transcript of meeting between members of Team B
Communication medium between distributed members: Skype
Present: Team B (all members), 1 facilitator and 1 researcher
Units of Analysis: Topic segments: 34, utterances of Participants: 345

Table 3 Description of dataset

Description of data
Meeting 1: problem definition phase Duration: 3 h
Content: Audio and transcript of meeting between members of the team
Present: All 4 team members and 1 researcher
Units of Analysis: Topic segments: 40, utterances of Participants: 637
Meeting 2: Ideation phase Duration: 1 h 25 min
Content: Audio and transcript of meeting between members of the team
Communication medium between one distributed member: Skype
Present: 3 of the 4 team members and 1 researcher
Units of Analysis: Topic segments: 37, utterances of Participants: 348
Meeting 3: Concept development phase Duration: 50 min
Content: Audio and transcript of meeting between members of the team
Present: 3 of the 4 team members and 1 researcher
Units of Analysis: Topic segments: 34, utterances of Participants: 274

the differences in the number of the teams between the cases may be a limitation of this study. The focus at each phase of the project was as follows:

- **Problem definition phase:** This involved scoring and filtering the needs observed during clinical immersion.
- **Ideation phase:** This involved developing ideas around a select few needs.

- **Concept development phase:** This involved the further development of design solutions around one need. Table 3 outlines the data.

Ethical approval was given for this research study by the researcher's institution. The ethical concerns taken into account included: anonymity, confidentiality and informed consent. To ensure anonymity all identifier components were removed for individuals, places and organisations and pseudonyms were used where names appear. The participants were advised of the nature and objective of the study and how information would be used and stored. Written consent was obtained from all participants. A reflexive approach was taken throughout the research to account for the presence of the researcher in the process and how this could influence the research. Overcoming this, required the researcher remaining objective and taking an 'outsider stance' to avoid influencing behaviours or outcomes.

Data analysis

While the research was predominantly inductive the literature review provided four overarching cognitive processes to expect within the data; *knowledge processing, critical thinking, creative thinking and meta-cognition.* These provided higher order categories to then inductively explore the conversation activities that make up these categories. Content analysis (CA) was used to analyse the data. This method focuses on the characteristics of language as communication, with attention to the content or contextual meaning of the text (Budd et al. 1967; McTavish and Pirro 1990). The data was first divided into manageable chunks through the identification of topic segments. Conversations usually cover a number of topics and involve shifts from one topic to the next. A topic segment is a piece of conversation that relates to a specific topic or focus. Once participants shift from a particular topic they have then moved to another topic. The analyst must make intuitive decisions about where one topic begins and ends (Yule and Brown 1983). Topic shifts and changes were considered to be appropriate means of dividing the data into topic segments (Bublitz 1988). Each topic was further divided into utterances. Utterances were bounded by the turn taking of participants and ranged from a word to a number of sentences.

Coding of the data

Four cognitive processes were identified from the literature to guide the empirical research: *knowledge processing, critical thinking, creative thinking and meta-cognition.* Four steps of coding followed:

Open coding of the data to inductively allow conversation activities to emerge.
Deductive coding of the data to categorise it into, *knowledge processing, critical thinking creative thinking and metacognition*
Consolidated coding where the inductive categories were merged and reduced.
Axial coding to link the conversation activities to the cognitive processes within each utterance. The data was then examined to see if a conversation activity was used as, *knowledge processing, critical thinking, creative thinking* or *meta-cognition.*

Table 4 Analysis of the data

Conversation activities	
Applying Domain knowledge	Specialist and expert knowledge of a particular domain including: **Stories** or **reference to prior experience**, or a particular case.
Constructing Analogies	Transferring information or meaning from a particular subject (the analogue or source) to another subject (the target). e.g.: Comparing the shape of a car to a fish.
Arguing	Give reasons for or against an idea, action, or theory, usually with the aim of persuading others to share one's view. Includes: questioning practices and not taking information for granted.
Constructing mental simulations	Where a sequence of interdependent events is consciously enacted or run through mentally to determine cause and effect relationships.
Constructing scenarios	Creating a mental picture of how someone would behave or feel in a certain situation. Imagining and predicting a situation. Scenarios enable empathy and understanding of the **perspective of others** by understanding how another might experience a situation.
Building on	Building on another's thoughts and ideas.

Findings

Six conversation activities were inductively uncovered that support the cognitive processes, see Table 4.

The following is an example from the Med-Dev case which outlines how the cognitive processes and conversation activities were used. The team were trying to develop solutions for *an easier way to manage faecal matter from an Ileostomy*[1] *that reduces the risks of skin complications and improves security.* The team were aiming to select a final concept. Consensus took time as solutions needed to be thoroughly critiqued and judged before team members could come to a decision. Differences in opinion forced the elaboration of and the analysis of the proposed solutions and strong negotiations. There were a few solution options and the team were discussing their suitability. Table 5 outlines a section of the conversation to show how consensus was reached. Until this point in the meeting agreement had not been reached. Kieran proposes an alternative solution to the ones previously discussed. The reaction is positive reflected in *creative thinking* and *building on* to develop the idea rather than critique it. He uses a *mental simulation* to suggest how the idea would work. This is further built on by both Riona and Kieran. Riona contributes to the idea by using *domain knowledge* to explain that there are bags that "are cut to size and ones that are pre-cut." An *analogy* is also made to vacuum cleaners to expand on the concept. Through the co-development of the idea, consensus is established at the end of the topic.

[1] An **ileostomy** is an opening in the abdominal wall that's made during surgery. The end of the ileum (the lowest part of the small intestine) is brought through this opening to form a stoma.

Table 5 Concept development discussion Med-Dev team

Examples	Cognitive processes	Conversation activities
Kieran: This part could be stiffer and smaller or bigger but if you could get bags with a standard shape cut out that slots into that perfectly every time.	CRT	Constructing a mental simulation
Riona: A snap fit	CT	Building on
Kieran: And your inner flowery type opening always guides the fluid in. They still stick on to each other then you are sure that there is no contact with the skin. The problem there probably is this hole. Maybe you have to sell exclusively Holister bags with a standard hole size.	CRT, CT	Constructing a mental simulation, building on
Riona: There are two different options of bags, you can get ones that are cut to size and ones that are pre-cut, so they can sell a pre-cut.	KP	Applying domain knowledge
Kieran: So they can do that.	KP	
Riona: So maybe just to further that if this was to go in you would nearly snap fit it in or that once it's in, there is a rim that goes out this way in it, hooks into it. It might be harder to get it in but once it's in; there is a lock on it.	CRT, CT	Constructing a mental simulation, building on
Researcher: Like vacuum cleaners.	CRT	Constructing an analogy
Kieran: That's a clever mechanical lock all right but I would still be hoping that the adhesive we currently use in bags and manufacture would suffice to stick the bag onto whatever we have so that there is no leaking.	CT	Arguing
Riona: I just thought that if you were getting direct contact between here and here that it is not touching the skin at all isn't that it?	KP	Constructing a mental simulation
Kieran: yeah that's it. **CONSENSUS**		

KP knowledge processing, *CT* critical thinking, *CRT* creative thinking, *MC* meta-cognition

The differences between expert and novices

Major differences were found between the expert Med-Dev team and the novice Undergraduate team. The experts had a higher frequency of cognitive processing per utterances and many of the utterances expressed by the novices could not be assigned to a cognitive process. These were statements that were off the topic or not task focused. This suggests that the expert's utterances were more productive and aimed at both the development of common ground and the progression of the project.

At the problem definition phase

The Med-Dev team applied more *critical thinking* associated with higher order thinking, problem solving reasoning and decision making. This was reflected in their ability to analyse and negotiate a shared understanding of the project information. They spent more time analysing information, investigating cause and effect relationships, identifying patterns and relationships and forming judgements. The Undergraduate teams, used *knowledge processing* most frequently and focused on the exchange of information rather than on the critical analysis of that information.

The novice teams particularly the Undergraduate Team B used less *domain knowledge,* less *arguing* and less *mental simulations* than the Med-Dev team. *Domain knowledge* was the foundation to the construction of discipline specific knowledge and the ability to explore and analyse the project in breadth and depth. The novices were hampered by their lack of *domain knowledge* and prior experience. Not only did the Med-Dev team have more *domain knowledge* but they were able to combine this with *critical thinking* to analyse the project information. They used *domain knowledge* to expand the problem space, form strong judgements and support *arguments*. The following compares two examples. The first involves the Undergraduate Team A as they try to establish factors that would affect the quality of the experience when in a crew rest. While the team identify that fresh air is important there's no expansion or critical analysis of the subject. There is consensus, but it is an easy consensus. The novice team also show high levels of *metacognition*. *Metacognition* can reflect higher order thinking but it was also associated with uncertainty and unsureness particularly for the Undergraduate Team A. The focus for this team was more about considering what the next item was to address and the management of the project rather than on the critical discussion needed to expand the problem space. Where *critical thinking* did occur it was still at a surface level without expansion.

Rachel: "What else can we say?"
Kieran: "The air"
Rachel: "Oh yeah the air."
Kieran: "Cool clean fresh air."
Rachel: "So just put in air and put in cool clean and fresh."
James: "So we're doing well here on freshness just looking at it."

The level and quality of *arguing* was also a differentiating factor between the experts and novices. The expert Med-Dev team applied a deeper level of analysis with stronger arguments. In the following example the team were debating if there were issues around the process of stomach feeding patients. *Domain knowledge* and *scenarios* were key activities that supported *arguing*:

Riona: "No. They have to go and get an x ray before they can feed the patient."
Liam: "Surly it's a minor improvement. If he goes into the lungs he just takes the tube out and it will just take another 5 min."
Riona: "But they don't know if they are in the lungs or the stomach so they have to go off and get an X-ray. And they can't get an X-ray immediately and it might take two days just to prove that the tube is in the stomach."

In addition *mental simulations* were conducted more frequently amongst the experts. This activity is also linked to *domain knowledge* as it requires the knowledge of the step by step interaction with a process:

Christy: "Every time you insert a feeding tube you send them for an X-ray. There are two types of NGs. There's a drainage tube if someone is nauseous, it's just for drainage you never put anything into it. You don't need to x-ray that, you just throw it down. A feeding tube is a really thin white or yellow line. You never put anything through a feeding tube until you have established that it is in the stomach."

In contrast while the novice teams *argued,* their arguments were less informed. The experts, in their use of *critical thinking* could question the contributions of others and did not readily accept information or practices as being correct. The use of *arguing* meant that these teams did not reach a premature consensus and when consensus was reached it was due to a thorough critique and exploration of the project elements. This would suggest that experts may delay consensus in order to have a thorough negotiation of the project information and a shared representation that in turn will bring about better decisions. In the following example Christy questions how a 'user need' is defined. He has a different perspective on how the 'need' should be emphasised. This is accepted by the team and revised. This reflects the expert's ability to reframe and restructure the problem through their proficiency in elaborating and negotiating knowledge.

Christy: "To me when you say a better way to manage hypothermia you have already allowed hypothermia to occur in the patient so I think it's the prevention of hypothermia that is the issue."

Kieran: "ok"

However the Undergraduate teams tried to compensate for their lack of *domain knowledge*. *Building on* was an activity linked to resolving uncertainty and was used by them to collectively piece together information by drawing out the related knowledge of each team member to structure the problem. *Analogies* also supported the novice teams to understand the problem. While the experts used *analogies* directly related to the topic the novices due to a lack of domain knowledge only constructed *analogies* indirectly related to the topic and from their own personal experiences. In the following example Lauren recounts a flying trip with young children to make a connection with the crew rest environment.

Lauren: "Again for example space for children because I have had the experience of having two children in the plane and people sleeping so it might be awkward for parents. What do I do if others are resting and the baby is crying?"

At the ideation phase

The Undergraduate teams used less *creative thinking* than the experts at this phase. They spent less time proposing ideas and a greater proportion of time critiquing ideas reflected in higher levels of *arguing* and *scenarios*. This led to a limitation in the number of ideas proposed and the chance to maximise solution options. The following is an example:

> Brian: "even if we could split the stairs so it could open or extend another small bit so you could walk in and get a little more room. I don't know.
>
> Lisa: "Yeah but for health and safety that's not going to be realistic. You know if the slope was in too far they're going to fall down and break their necks."

In contrast the Med-Dev team used more *critical thinking* to further analyse the problem to understand the solution requirements. In the following example Kieran uses *critical thinking* to analyse the current approaches and issues when trying to surgically remove adhesions.

> Kieran: "So you have two layers of tissue stuck together by adhesions and if you try to lift this you lift this as well. To address it as far as I could see they stick an injection in there and they inject saline water and salt in between the two layers and force a bit of separation in order to gain access to two different planes."

By understanding the problem in more depth Kieran was then able to make a proposal that involved looking at the problem from a new perspective.

> Kieran: "What about going from the other angle instead of trying to address all the adhesions and trying to find all the adhesions, just spending your time separating the fascial layer of the peritoneum cavity from everything else?"

The notable difference between the teams was while the novice team engaged in *critical thinking* in the early critique of ideas, the Med-Dev team applied *critical thinking* mainly to expand the problem which supported idea generation. Experts appear to be better at maintaining this balancing.

In developing solutions the Med-Dev team were more adept at drawing support from their *domain knowledge* which in turn better equipped them to use *mental simulations* to examine step by step procedures and explain ideas and construct *analogies* to draw ideas from other applications. The experts were more effective at using *analogies* to transfer ideas from a variety of sources. While the novices were inclined to simply explain with *analogies*, *analogies* supported the Med-Dev team to analyse the problem further, make comparisons to similar cases and in turn propose solutions. The quality of the *analogies* and *mental simulation*s created by the experts were at a higher level in terms of the detail explored. They were more proficient in applying these activities to clearly communicate their reasoning of more complex information. In the following example Kieran from the Med-Dev team uses the *analogy* of scar tissue to propose an idea for treating adhesions. In using a *mental simulation* within the *analogy* to propose and explain an idea he gathers support from his team members.

> Kieran: "If you pull a muscle you get scar tissue around the muscle. You get fibrous tissue and that stays there and the muscle isn't right until that scar tissue is broken down and massaged. So if you perform surgery on an abdominal injury you'll have scar tissue, fibrous tissue that you need to massage out to prevent or

reduce the effect of the adhesions. If you pull a muscle and a scar tissue forms you can get ultra sound treatment, you can get electrical stimulation treatment. So I wonder would ultra sound or electrical simulation work to breakdown or reduce the scar formation post-surgery for adhesions or improve the breaking down of the fibrous tissue."

Liam: "Yeah, if it would work, it would be like a device to put on after surgery while they are in hospital to administer some kind of ultra sound to stop the scaring."

While the novice teams made *analogies* they were from team member's limited personal experiences and lacked the same depth of knowledge that the experts had.

Lisa: Like a shower, I have a shower at home where you pull the two side doors, you pull the front one and then the side one, so that could be the same thing.

At the concept development phase

The significant difference between the experts and novices at this phase was that the experts engaged in much more *critical thinking* and showed a greater level of analysis of concepts and a higher frequency of *arguing*.

The Med-Dev team also analysed proposed concepts from a variety of perspectives and considered several issues together. The novices generally reviewed proposed concepts from one perspective and only focused on few issues. For example in reviewing concepts to prevent dermatitis and leakage with ileostomy bags the expert team were able to assess the functionality of the product but also looked at the concept in terms of manufacturability, cost, and the different requirements of each of the stakeholders:

Liam: "You could use the backing like here, or put the glue on it even as an option if we are pitching to H. You could say that you make it out of the Hemmingway and the only new material involved in the whole process for them is this. They don't have to think about making these in silicone."

The novices seemed to be anxious to get agreement on a concept selection from their distributed team members at the expense of a thorough analysis of the solution. In contrast the expert teams at times delayed consensus to thoroughly explore and develop concepts. They recognised the limitations of proposed solutions and deferred decision making until they had evidence and proof. Knowing when a team is in a position to make a decision is therefore a necessary skill:

Riona: We need to work on more of the detail on this. What do you think?
Liam: yeah I think so.
Riona: let's make up some prototypes and see.

In summary the experts used more cognitive processes and conversation activities than the novices, particularly *critical thinking* and *domain knowledge* reflecting higher order thinking. They deferred decision making at times to reframe, elaborate and negotiate on the project information and treated problems as more complex. The expert's high level of *domain knowledge* supported them in a more effective use of the conversation activities: *analogies*, *arguing* and *mental simulations*. The experts appeared to be better at deferring judgement on early ideas and better at judging when to argue.

Discussion

While interdisciplinary team work is the norm in industry it is difficult to implement in an educational setting due to the difficulties around assessment, grading and facilitation. This may be due to a lack of clear criteria to identify what constitutes good collaboration and good discussion in teams. However it has been shown that formative assessment is essential for deep learning (Lynch and Hennessy 2017). If developing effective teamwork strategies is a goal, then teachers need to also assess the collaboration process (Fredrick 2008). It will therefore become necessary to understand what constitutes constructive and effective dialogue amongst students.

This study has revealed and compared the cognitive processes and conversation activities used between experts and novices in interdisciplinary teams in the course of design projects. Previous research has demonstrated different traits between expert and novice problem solving performance in design (Björklund 2013; Lawson and Dorst 2013). This research has built on those findings showing that experts within teams engaged in more constructive dialogue than novices to: share, elaborate on and negotiate on project information and make decisions. They applied higher order thinking by engaging more effectively in the cognitive processes of: *knowledge processing, critical thinking, creative thinking and metacognition*. Previous literature had not drawn together all four cognitive processes. This research confirmed that there were four key cognitive processes engaged with by the teams and particularly by the expert team. To support these thinking modes the experts spontaneously used more often and more constructively a number of conversation activities: *applying domain knowledge, constructing analogies, arguing, constructing mental simulations, constructing scenarios and building on*. By comparing the cognitive activity of both novices and experts within design teams it is possibly to transfer these insight to support novices in design teams to become expert practitioners. These cognitive processes and conversation activities identified can also be used by facilitators to prompt and scaffold team conversation as well as acting as a guide to assess the quality of team discussion.

The conversation activity of the experts showed that they seemed to realise the importance of processing greater amounts of information and considering alternative perspectives, which in turn delayed decisions. These findings support the literature to show that experts will spend more time in defining the problem, activating prior knowledge and elaborating on the information presented (Brand-Gruwel et al. 2005). The experts in accordance with the literature treated problems as more complex, and delayed decisions to ensure the thorough elaboration and negotiation of the problem and carry out iterative shared representations or frames. They seemed to be better at judging where further elaborations were necessary and when decisions should be delayed. The ability to frame and reframe is also associated with high levels of expertise (Paton and Dorst 2011). The findings indicate that the more novice teams were inclined to seek earlier decisions which prevented the same depth of exploration and discussion. Therefore it may be important to encourage student teams to delay consensus and decision making in order to further elaborate on project elements.

The novice's lack of *domain knowledge* limited them in elaborating on and expanding the problem space which in turn limited their use of the conversation activities that were instrumental in enabling the experts to progress effectively. This raises questions around creating interdisciplinary education with undergraduate students. It has been shown that successful interdisciplinary work must be grounded in the core disciplines (Mansilla and Duraising 2007). If students are still novices within their core discipline their ability to contribute within an interdisciplinary framework may be limited. Interdisciplinary approaches may therefore be more constructive at a postgraduate level. However close facilitation of novice teams can be used to encourage them to delay consensus and treat problems as difficult in order to increase their levels of *critical thinking* and conversation activities. Student teams may need to be afforded time to research in order to bring about more *domain knowledge*. In addition as advocated by Deken et al. (2012) an important means of acquiring knowledge is to consult experienced colleagues or experts. The provision of analogous cases can also make up for a shortfall in experience and domain knowledge. In doing so, the novice may begin to build that experience base to become an expert. Students should be encouraged to question and negotiate on project information to promote better arguments. Attention should also be given to the purpose of the phase for example an emphasis of *metacognition* at the early phase and the encouragement of *creative thinking* at the ideation phase. An overemphasis of arguing would not be appropriate at the ideation phase, but should be encouraged at the concept development phase to critique ideas.

In order to teach and assess student teams' ability to collaborate, facilitators will need to be able to prompt students' interactions and also measure the success of the engagement. The conversation activities outlined in this study could provide a basis to prompt and scaffold student discussions. They can also be used as a means to assess the quality of the dialogue of the teams. However this demands, as advocated by Lee (2014), an increased effort in the facilitation of interdisciplinary and collaborative learning.

The study has some limitations. The study did not address the individual, gender and cultural differences between the team members. It also did not address the effect of team members being distributed. Therefore the comparative findings must be taken with caution. Further studies would be worthwhile to understand these differences. The findings from this research are also based on a small number of participants so it is not possible to generalise from the findings. Despite these limitations, the connections between these findings and the literature on expertise suggests, that it would be worthwhile to replicate the study with larger groups. Another avenue of future work would be to develop a scaffolding model based on the findings and test it with student groups to determine its benefits.

Conclusions

Putting novice students into teams does not mean that they will collaborate effectively. The findings point to the need for careful facilitation of team discussion in order to teach students to engage in productive dialogue. Team work is the norm in industry due to the scope and complexity of today's design problems. Including teamwork skills into the curriculum can also contribute to future employability. Learning from expert teams and applying these insights to novice teams can support novices towards expertise. As design expertise levels increase so does the ability to deal with complex, networked and dynamic problems (Lawson and Dorst 2013). The degree and experience and proficiency of educators to implement team work, assessment structures and grading means that educators may place more emphasis on project outputs rather than on the process inputs and the collaborative exchanges required to work effectively within a team (Riebe et al. 2016). The finding of this study can help to provide an understanding for educators of what constitutes productive dialogue while also providing the means and support to implement, facilitate and assess team work.

References

Ahmed, S., Wallace, K. M., & Blessing, L. T. (2003). Understanding the differences between how novice and experienced designers approach design tasks. *Research in Engineering Design, 14*(1), 1–11.

Andres, H. P. (2013). Team cognition using collaborative technology: A behavioral analysis. *Journal of Managerial Psychology, 28*(1), 38–54.

Atman, C. J., Adams, R. S., Cardella, M. E., Turns, J., Mosborg, S., & Saleem, J. (2007). Engineering design processes: A comparison of students and expert practitioners. *Journal of Engineering Education, 96*(4), 359–379.

Badke Schaub, P., Goldschmidt, G., & Meijer, M. (2010). How does cognitive conflict in design teams support the development of creative ideas? *Creativity and Innovation Management, 19*(2), 119–133.

Baker, M. (2009). Argumentative interactions and the social construction of knowledge. In N. M. M. A.-N. Perret-Clermont (Ed.), *Argumentation and education: Theoretical foundations and practices* (pp. 127–144). Berlin: Springer.

Björklund, T. A. (2013). Initial mental representations of design problems: Differences between experts and novices. *Design Studies, 34*(2), 135–160.

Bolton, M. K. (1999). The role of coaching in student teams: A "just-in-time" approach to learning. *Journal of Management Education, 23*(3), 233–250.

Brand-Gruwel, S., Wopereis, I., & Vermetten, Y. (2005). Information problem solving by experts and novices: Analysis of a complex cognitive skill. *Computers in Human Behavior, 21*(3), 487–508.

Bublitz, W. (1988). *Supportive fellow speakers and cooperative conversations*. Cambridge: University Press.

Budd, R. W., Thorp, R. K., & Donohew, L. (1967). *Content analysis of communications*. New York: Macmillan.

Casakin, H., Davidovitch, N., & Milgram, R. M. (2010). Creative thinking as a predictor of creative problem solving in architectural design students. *Psychology of Aesthetics, Creativity, and the Arts, 4*(1), 31.

Chiu, M.-L. (2002). An organizational view of design communication in design collaboration. *Design Studies, 23*(2), 187–210.

Choi, I., & Lee, K. (2009). Designing and implementing a case-based learning environment for enhancing ill-structured problem solving: Classroom management problems for prospective teachers. *Educational Technology Research and Development, 57*(1), 99–129.

Chou, W. H., & Wong, J. J. (2015). From a disciplinary to an interdisciplinary design research: Developing an integrative approach for design. *International Journal of Art & Design Education, 34*(2), 206–223.

Christensen, B. T., & Ball, L. J. (2016). Creative analogy use in a heterogeneous design team: The pervasive role of background domain knowledge. *Design Studies, 46,* 38–58.

Christiaans, H. (1992). *Creativity in design*. Delft: Delft University of Technology.

Cross, N. (1990). The nature and nurture of design ability. *Design Studies, 11*(3), 127–140.

Cross, N. (2001). Design cognition: Results from protocol and other empirical studies of design activity. In M. M. W. N. C. Eastman (Ed.), *Design knowing and learning: Cognition in design education* (pp. 79–103). Amsterdam: Elsevier.

Cross, N. (2004). Expertise in design: An overview. *Design Studies, 25*(5), 427–441.

Cross, N. (2006). *Designerly ways of knowing*. London: Springer.

De Vere, I., Melles, G., & Kapoor, A. (2010). Product design engineering—A global education trend in multidisciplinary training for creative product design. *European Journal of Engineering Education, 35*(1), 33–43.

Defazio, J. (2008). The identification of design experts. *Journal of Design Research, 7*(1), 84–96.

Deken, F., Kleinsmann, M., Aurisicchio, M., Lauche, K., & Bracewell, R. (2012). Tapping into past design experiences: Knowledge sharing and creation during novice–expert design consultations. *Research in Engineering Design, 23*(3), 203–218.

Détienne, F., Baker, M., & Burkhardt, J.-M. (2012). Quality of collaboration in design meetings: Methodological reflexions. *CoDesign, 8*(4), 247–261.

Dong, A. (2007). The enactment of design through language. *Design Studies, 28*(1), 5–21.

Dorst, K. (2011). The core of 'design thinking'and its application. *Design Studies, 32*(6), 521–532.

Dorst, K., & Cross, N. (2001). Creativity in the design process: Co-evolution of problem–solution. *Design Studies, 22*(5), 425–437.

Facione, P. A. (1998). *Critical thinking: What it is and why it counts*. Millbrae, CA: California Academic Press.

Ferreira, D. J., & Lacerda dos Santos, G. (2009). Scaffolding online discourse in collaborative ill-structured problem-solving for innovation. *Informatics in Education-An International Journal, 8_2,* 173–190.

Flavell, J. H. (1979). Metacognition and cognitive monitoring. *American Psychologist, 34*(10), 906–911.

Fredrick, T. A. (2008). Facilitating better teamwork: Analyzing the challenges and strategies of classroom-based collaboration. *Business Communication Quarterly, 71*(4), 439–455.
Garbuio, M., Dong, A., Lin, N., Tschang, T., & Lovallo, D. (2018). Demystifying the genius of entrepreneurship: How design cognition can help create the next generation of entrepreneurs. *Academy of Management Learning & Education, 17*(1), 41–61.
Goel, V., & Pirolli, P. (1989). Motivating the notion of generic design within information-processing theory: The design problem space. *AI Magazine, 10*(1), 19.
Goldschmidt, G. (2016). Linkographic evidence for concurrent divergent and convergent thinking in creative design. *Creativity Research Journal, 28*(2), 115–122.
Goldschmidt, G., & Rodgers, P. A. (2013). The design thinking approaches of three different groups of designers based on self-reports. *Design Studies, 34*(4), 454–471.
Goldschmidt, G., & Tatsa, D. (2005). How good are good ideas? Correlates of design creativity. *Design Studies, 26*(6), 593–611.
Haupt, G. (2015). Learning from experts: Fostering extended thinking in the early phases of the design process. *International Journal of Technology and Design Education, 25*(4), 483–520.
Hong, Y.-C., & Choi, I. (2011). Three dimensions of reflective thinking in solving design problems: A conceptual model. *Educational Technology Research and Development, 59*(5), 687–710.
Hung, W., Jonassen, D. H., & Liu, R. (2008). Problem-based learning. In J Gv J M Spector, M. D. Merrill, & M. Driscoll (Eds.), *Handbook of research on educational communications and technology* (3rd ed., Vol. 3, pp. 485–506). Mahwah, NJ: Erlbaum.
Jain, V. K., & Sobek, D. K., II. (2006). Linking design process to customer satisfaction through virtual design of experiments. *Research in Engineering Design, 17*(2), 59–71.
Jakobsson, A. (2006). Students' self-confidence and learning through dialogues in a net-based environment. *Journal of Technology and Teacher Education, 14*(2), 387.
Jonassen, D. H. (1997). Instructional design models for well-structured and III-structured problem-solving learning outcomes. *Educational Technology Research and Development, 45*(1), 65–94.
Jonassen, D. H. (2003). Using cognitive tools to represent problems. *Journal of research on Technology in Education, 35*(3), 362–381.
Jonassen, D. H. (2008). Instructional design as design problem solving: An iterative process. *Educational Technology, 48*(3), 21–26.
Jonassen, D. H., & Hung, W. (2008). All problems are not equal: Implications for problem-based learning. *Interdisciplinary Journal of Problem-Based Learning, 2*(2), 4.
Jones, J. (1992). *Design methods* (2nd ed.). New York: Wiley.
Kiernan, L., & Ledwith, A. (2014). Is design education preparing product designers for the real world? A study of product design graduates in Ireland. *The Design Journal, 17*(2), 218–237.
Kim, K., Kim, N., Jung, S., Kim, D.-Y., Kwak, Y., & Kyung, G. (2012). A radically assembled design-engineering education program with a selection and combination of multiple disciplines. *International Journal of Engineering Education, 28*(4), 904–919.
Kleinsmann, M., Deken, F., Dong, A., & Lauche, K. (2012). Development of design collaboration skills. *Journal of Engineering Design, 23*(7), 485–506.
Lawson, B., & Dorst, K. (2013). *Design expertise* (2nd ed.). Oxford: Architectural Press.
Lee, J. (2014). The integrated design process from the facilitator's perspective. *International Journal of Art & Design Education, 33*(1), 141–156.
Lynch, R., & Hennessy, J. (2017). Learning to earn? The role of performance grades in higher education. *Studies in Higher Education, 42*(9), 1750–1763.
Mansilla, V. B., & Duraising, E. D. (2007). Targeted assessment of students' interdisciplinary work: An empirically grounded framework proposed. *The Journal of Higher Education, 78*(2), 215–237.
McTavish, D. G., & Pirro, E. B. (1990). Contextual content analysis. *Quality & Quantity, 24*(3), 245–265.
Mercer, N., & Littleton, K. (2007). *Dialogue and the development of children's thinking: A sociocultural approach*. London: Routledge.
Mol, E., Khapova, S. N., & Elfring, T. (2015). Entrepreneurial team cognition: A review. *International Journal of Management Reviews, 17*(2), 232–255.
Mosely, G., Wright, N., & Wrigley, C. (2018). Facilitating design thinking: A comparison of design expertise. *Thinking Skills and Creativity, 27,* 177–189.
Nae, H.-J. (2017). An interdisciplinary design education framework. *The Design Journal, 20*(sup1), S835–S847.
Paton, B., & Dorst, K. (2011). Briefing and reframing: A situated practice. *Design Studies, 32*(6), 573–587.
Paulus, P. (2000). Groups, teams, and creativity: The creative potential of idea-generating groups. *Applied Psychology, 49*(2), 237–262.

Popovic, V. (2003). General strategic knowledge models connections and expertise development in product design. In N. Cross & E. Edmonds (Eds.), *Expertise in design: Proceedings of DTRS'6* (pp. 251–270). Sydney: Creativity and Cognition Studios.

Riebe, L., Girardi, A., & Whitsed, C. (2016). A systematic literature review of teamwork pedagogy in higher education. *Small Group Research, 47*(6), 619–664.

Runco, M. A., & Acar, S. (2012). Divergent thinking as an indicator of creative potential. *Creativity Research Journal, 24*(1), 66–75.

Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. *Creativity Research Journal, 24*(1), 92–96.

Schön, D. (1983). *The reflective practitioner*. New York: Basic Books.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review, 7*(4), 351–371.

Seidel, V. P., & Fixson, S. K. (2013). Adopting design thinking in novice multidisciplinary teams: The application and limits of design methods and reflexive practices. *Journal of Product Innovation Management, 30*(S1), 19–33.

Self, J. A., & Baek, J. S. (2017). Interdisciplinarity in design education: Understanding the undergraduate student experience. *International Journal of Technology and Design Education, 27*(3), 459–480.

Smith, K. M. (2015). Conditions influencing the development of design expertise: As identified in interior design student accounts. *Design Studies, 36,* 77–98.

Stempfle, J., & Badke-Schaub, P. (2002). Thinking in design teams-an analysis of team communication. *Design Studies, 23*(5), 473–496.

van Ginkel, W., Tindale, R. S., & van Knippenberg, D. (2009). Team reflexivity, development of shared task representations, and the use of distributed information in group decision making. *Group Dynamics: Theory, Research, and Practice, 13*(4), 265.

van Ginkel, W., & van Knippenberg, D. (2008). Group information elaboration and group decision making: The role of shared task representations. *Organizational Behavior and Human Decision Processes, 105*(1), 82–97.

Xun, G., & Land, S. (2004). A conceptual framework for scaffolding III-structured problem-solving processes using question prompts and peer interactions. *Educational Technology Research and Development, 52*(2), 5–22.

Yin, R. K. (1994). *Case study research design and methods* (2nd ed.). London: Sage.

Yule, G., & Brown, G. R. (1983). *Discourse analysis*. Cambridge: University Press.