Examining the Spatial Ability Phenomenon from the Student's Perspective

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Abstract

This phenomenological investigation examined the lived experience of technically-oriented students over the course of a single semester, attempting to answer the question, "What was it like for a student to experience the spatial ability phenomenon?" The study included 12 interviewees and 8 focus group freshman participants at a Midwestern university. Data sources included interview transcripts, think aloud transcripts, task solutions, focus group transcripts, researcher journal entries, course performance data, course observation data, and spatial ability test data. This paper provides the holistic, structural description of the spatial phenomenon that emerged from the descriptions of the participants' experience, as well as an expository on four of the five invariant themes that were elicited from the data. the collaborative session. Recommendations were made for future course improvements when a real world project is used in the curriculum. This paper also discusses changes in design process and the role of designers based on the collaborative session feedback.

INTRODUCTION

Ever since I began teaching, I have always been curious; what interventions aid in the improvement of the spatial ability of students? Watching other faculty and reviewing the related literature, the approaches and the results sometimes seem indiscriminate. Upon further study and when combined with my own classroom experiences, it became clear that spatial ability, while noticeably present or absent as evidenced by student performance, is much harder to define and definitively measure than one would suspect.

In many fields, researchers are striving for the same thing: unlocking the secret of spatial ability so that students may be more successful in their chosen field. Much research has been devoted to the use of specific interventions, but none has focused on understanding the individual's perspective and the experience of the phenomenon using a qualitative approach. How would a student describe spatial ability? What would he or she report as inhibitors of this ability? What would he or she say helps exercise spatial ability? What would a student report as relevant experiences, background, or education?

Attempting to answer these questions through student perspectives was the goal of this research. Its purpose was to provide insight into the background, life experiences, and perceptions of specific individuals in relation to spatial activities.

RELEVANT LITERATURE

Inconsistency in nomenclature and associated definitions has hindered spatial ability research. Many researchers have acknowledged the problems this has caused, not just in communication and understanding, but also in terms of devices for measuring spatial ability and the broad comparison of research results (D'Oliveira, 2004; Eliot & Smith, 1983; Lohman, 1979).

Spatial ability research has been approached from several psychological and technological vantages since its beginnings as early as the late 1800s. The recognition that a distinct space factor existed separate from general intelligence occurred through the work of Kelley (1928), El Koussy (1935), Thurstone (1938) and Thorndike (1921). Following this, using factor analysis researchers sought to define what composed spatial ability, without regard to how the ability developed or what processes were involved within it. Research by Slater (1940), Thurstone (1950), Guilford and Lacy (1947), French (1951), used this approach.

The research then split into a several different directions. Several researchers examined spatial ability from an information processing viewpoint, in which they strove to understand the processes involved in the development and use of spatial cognition (Cooper, 1982; Kyllonen, 1984; Lohman, 1988; Pellegrino & Hunt, 1991). Other researchers examined spatial ability from a developmental perspective, looking at the development of spatial ability from childhood (Olson, 1975; Piaget & Inhelder, 1971). And, still others examined spatial ability from a strategy perspective (Kyllonen, Woltz, & Lohman, 1981; Lohman & Kyllonen, 1983) or differential perspective (Harris, 1978; Lohman, 1984; Linn & Petersen, 1986; McGee, 1979a; Maccoby & Jacklin, 1974; Nyborg, 1983; Voyer, Voyer, & Bryden, 1995). Interested readers may wish to review historical accounts (Carroll, 1993; Eliot & Smith, 1983; Smith, 1964).

A review of literature reveals that the most generic and commonly accepted definition of spatial ability was provided by Lohman (1979) following a comprehensive reanalysis of the seminal research that preceded him. Today it is accepted that spatial ability is not a unitary construct, but rather a collection of factors, even though early research referred to a single space factor. Lohman (1979) states that "spatial ability may be defined as the ability to generate, retain, and manipulate abstract visual images (p 188)." In that same report, he acknowledged that spatial ability was composed of three primary factors (relations, orientation, and visualization) and several minor factors. He defined (1) spatial relations as mental rotations and the ability to solve spatial problems quickly, (2) spatial orientation as the ability to relocate the viewer and discriminate between left and right, and (3) spatial visualization as the ability to solve complex spatial problems that facilitate the use of multiple spatial and peripheral factors. More recent work by Carroll (1993) has reiterated Lohman's findings in this area and provided a unique viewpoint on intelligence and its composition.

SIGNIFICANCE

Quantitative research is almost ubiquitously performed within the spatial ability domain. From an analysis of gender differences to spatial ability interventions, such research has a long quantitative history. However, little attention has been paid to introspectively inquiring of the participants why they are successful or unsuccessful with spatial material. Researchers such as Lohman and Kyllonen (1983) have indicated that the qualitative research approach could add much to the understanding of spatial ability if researchers were to begin using such methods. Therefore, the qualitative research approach seemed to be the best method of not only answering the questions posed in this research, but had the potential to provide a unique contribution to the field.

PURPOSE

The purpose of this research was to elicit, describe, and analyze the background, life experiences, and perspectives of individuals with varying levels of spatial ability answering the question, "What was it like for a student to experience the spatial ability phenomenon?"

RESEARCH QUESTIONS

Each of the questions addressed in this research was intended to reveal the phenomena of spatial ability and its structure through the lived experience of the participants. The goal was to reveal patterns that are seen in high and low visualization ability students and consider how we might learn from these patterns to provide more effective instruction. To exemplify this, the differences in lived experiences between those classified as high and low were focused upon. To the extent that the study describes the lived experience of the participants and their experience with the spatial phenomenon is the extent to which the study is inclined toward the phenomenological framework (Patton, 2002). Questions central to this research were:

1. *What do students report as their person al background (gender, parental occupa tion, parental involvement, or family income) that could have contributed to their strength or weakness in spatial ability?*
2. *What personal experiences (hobbies and childhood or teenage experiences) or academic experiences (favorite courses, teachers or subjects) have contributed to their ability or inability?*
3. *How do students approach spatial activi ties given their level of spatial ability, that is, what are their attitudes, thought processes, and perceptions surrounding such activities?*

METHODOLOGY

This research used the tools of qualitative research methodology in the form of interviews, observations, and focus groups and was founded upon the phenomenological perspective. As a mode of inquiry, phenomenology examines participant meanings garnered from their experiences to improve understanding (Van Manen, 1990). Its primary focus is "to explore how human beings make sense of experience and transform experience into consciousness, both individually and as shared meaning" (Patton, 2002, p. 104).

The sample for this study was selected from students in the Computer Graphics Technology course *CGT 163: Introduction to Graphics for Manufacturing* during the spring semester of 2006 at Purdue University's West Lafayette campus. CGT 163 was predominantly populated with freshman engineering students and it focused on freehand sketching and computer-aided design (CAD) to convey engineering ideas.

Qualitative studies typically focus on a range of individual cases that are selected purposefully. Extreme or deviant case sampling was used it this study. Patton (2002) defines this as:

> *...learning from unusual manifestations of the phenomenon of interest, for example, outstanding successes/notable failures; top of the class/dropouts; exotic events; crises (p. 243).*

For this study, students who exhibited high spatial ability and low spatial ability were the extremes selected. The Vandenberg Mental Rotations Test (1971) was selected as a measurement instrument to make this determination due to its reliability, validity, and convenience. Vandenberg and Kuse (1978) reported their use of the MRT test yielded an internal consistency metric of .88 and a test-retest reliability metric of .83. Zimowki and Wothke (1986) have shown that the MRT is a valid measure of spatial ability through correlations with other measures. And, according to the University of Colorado Boulder, the Vandenberg MRT is now considered public domain.

Single cases are often used in qualitative studies. However, Morse (1994) suggests that at least six participants be used in studies where one is trying to understand the essence of an experience. Creswell (1998) and Riemen (1986) recommend 10 and Dukes (1984) recommends studying 3 to 10 subjects. Based on these sources, 12 students were selected to participate in in-depth interviews; and 8 students participated in one of two focus groups, totaling 20 participants in all. Assignment of students to interviews or focus groups was conducted based on MRT score and then gender, major, and semester such that both interviewees and focus group participants were balanced across these variables to the extent possible. This was important so that data from the interviews and focus groups could be triangulated in the data analysis.

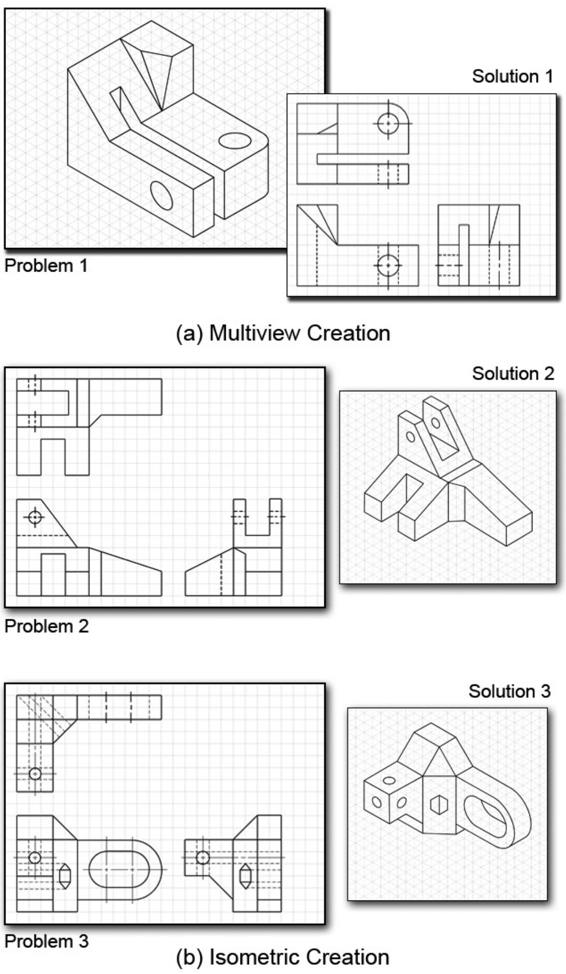

Figure 1. *Participants used a think aloud technique while solving (a) one multiview creation problem and (b) two isometric pictorial creation problems.*

DATA COLLECTION

While data was collected and from several different sources for triangulation purposes, interviews were primary. Interviewees participated in three, 90-minute interviews. The first was aimed at eliciting background and experiences that the interviewee believed affected their spatial ability. The second interview required that participants solve three problems using a talk-aloud technique. As shown in Figure 1, one problem required that they sketch the multiviews of a pictorial, while the other two required that they generate an isometric pictorial from given multiviews. The final interview was used as a summative activity, having the participant reflect on the development of their spatial ability during the semester, their learning in the course, and participation in the study.

DATA ANALYSIS

The data analysis for this study was based upon Giorgi's procedural recommendations (1985; 1987). The three major steps in this process were bracketing, intuiting, and describing. Bracketing requires one to set aside beliefs so that the phenomenon can be seen without the shroud of preconception or presupposition affecting it. Often bracketing occurs throughout the research using epoché. There were 5 epoché sessions that were conducted. In three of these sessions, the researcher addressed the same questions and problems in which the participants engaged. The other two presented the researcher's viewpoint of spatial ability before and after the data collection.

Intuiting allows one to develop meaning units based on the textural descriptions of the participants. After transcription of each of the data sources (interviews, interview notes, think aloud tasks, focus groups, and researcher journal), each transcription was read holistically, and then analyzed; looking for intentional experiences of the spatial ability phenomenon. This led to the development of meaning units or themes in terms of the spatial ability phenomenon.

The last step in the data analysis was to create a structural description of the meaning units, written in psychological language relative to the spatial ability phenomenon. Merleau-Ponty (1962) described the coalescence of the phenomenon (based on the created meaning units) as its structure. Thus, the narrative description of meaning units becomes the structural description. Whereas the textural description of the phenomenal experience is in the words of the participants, the structural description is the narrative that ties together the meaning units derived from the former.

INVARIANT THEMES

A review of the various data across each of the sources revealed five major, emergent themes, as shown in Table 1. The following sections will outline the findings relative to four of these themes.

BACKGROUND AND EXPERIENCES

Four areas seemed to surface as topics the participants believed were highly relevant to spatial development. These included childhood toys, favorite school subject, musical experience, and involvement in sports.

Childhood Toys. One of the overarching discussions in spatial ability research is the nature versus nurture argument, that is, which is the source of spatial ability differences. The nature argument posits childhood experiences, as well as access to toys and other experiences, as the basis for the development of spatial ability (Berry, 1971; Conner, Serbin, & Schackman, 1977; Stumpf & Klieme, 1989). Many have conducted research into toys, toy stereotyping, and the effect of toy access on spatial development (Fisher-Thompson, 1990; Tracy, 1987, 1990; Vandenberg, Kuse, & Vogler, 1985).

The biological position argues that due to heredity, hormones, or even genetics, individuals are predisposed to partake in certain activities or to exhibit certain abilities (Hall & Kimura, 1995; Linn & Petersen, 1984; Mann, Sasanuma, Sakuma, & Masaki, 1990; Sanders, Cohen, & Soares, 1986). However, contemporary thoughts on the subject of spatial ability and development argue that it is likely a mix of environmental and biological factors (Allen, 1974; Brosnan, 1998; Casey, Nuttall, & Pezaris, 1999; Harris, 1978; Vandenberg, Stafford, & Brown).

When asked about the childhood experiences that they thought affected their spatial ability, participants overwhelmingly reported that play activities with physical toys, particularly Legos, were a factor. All six of the high spatial ability participants (HSPs) referred to Legos, as did three of the low spatial ability participants (LSPs). Two of the other LSPs acknowledged having access to Legos, but that they were not something in which they were overly interested as a child. Three of the four high spatial ability focus group participants (HFGs) also acknowledged play activities with Legos.

Table 1.

Five Themes Emerged in This Study.

Themes	Description
1. Background and Experiences	Emergent areas of interest included childhood toys, musical background, favorite courses, and involvement with sports.
2. Characteristics	Notable similarities or differences between ability levels while problem solving
3.Common Errors	Observed or reported errors made in solving spatial tasks
4. Approaches and Processes	Techniques for solving spatial problems
5. Feelings	Various feelings observed or expressed by participants

That the high ability participants acknowledged Lego play activities was not surprising. In fact, this agrees with the literature (Brosnan, 1998). It was surprising, however, that three of the LSPs acknowledged playing with Legos, even though their MRT scores were initially low and their course performance was modest. As the researcher pondered this, he returned to the initial data. He wondered if there was a difference with how, or how much, they played with Legos. While indeed all three LSPs acknowledged play activities with Legos, comparing their statements to those made by HSPs, revealed a qualitative difference in the amount of time, depth of play, or the personal significance of the activity.

Favorite School Subject. Literature on spatial ability often presents two generalities relative to study in school. The first generality says that high visualizers often have difficultly with verbal skills, including grammar, punctuation, and spelling (Barton, Cattell, & Silverman, 1974; Fennema & Tartre, 1985; Gardner, 1993; West, 1997). Second, the literature often touts the positive correlative relationship between ability in math and spatial ability (Aiken, 1971; Fennema, 1974; Fennema & Sherman, 1977; Piascik, 1998; Shea, Lubinski, & Benbow, 2001).

The verbal skills acknowledged by both the HSPs and the LSPs did not agree with generalizations made about the relationship of spatial ability with verbal ability in the literature. There seemed to be no consistency; in both groups there were participants who reported being strong in verbal skills (specifically grammar, spelling, and punctuation) and those who reported being weak in those areas. Similarly, there seemed to be no tendency for the gender stereotype either.

Yet, an overarching commonality found in the data was focused on math as a subject of interest or ability. All of the HSPs acknowledged that math was their favorite course and all of the HFGs said math was their favorite subject also. Background questionnaires from the HSPs and HFGs corroborate this; when asked if they considered themselves strong in math, the participants selected "yes."

While the HSPs overwhelmingly said that math was their favorite subject, only two of the LSPs said math was their favorite. Even so, the data from this study seemed to corroborate findings in the literature that demonstrate a positive relationship between math and spatial ability. It is assumed that participants performed well in math if they stated that "they liked math" or that it was "easy for them." In the literature, math ability and spatial ability are typically positively correlated: Aiken (1975) reported .52, Baldwin (1976) .60, and Clements and Battista (1977) .30 to .60. Spatial ability has been reported as a good predictor of mathematical knowledge or ability also (Brown & Wheatley, 1989; Burnett, Lane, & Dratt, 1979; Shea et al, 2001; Fennema & Tartre, 1985; Friedman, 1995; Landau, 1984; Mason, 1986; Moses, 1977; Rhoades, 1981; Robichaux, 2000; Tillotson, 1984).

Musical Experience. Literature on spatial ability includes several studies that show a relationship between spatial ability and musical ability (Harris, 1978; Hassler, Burbaumer, & Feil, 1985; Heitland, 2000a, 2000b; Mason, 1986; McKelvie & Low, 2002; Newman, Rosenbach, Burns, Latimer, Matocha, & Voghtm 1995; Rauscher, Shaw, & Ky, 1993, 1995; Rauscher, Shaw, Levine, & Ky, 1994; Robichaux, 2000). The results of the present study revealed that while most of the HSPs have extensive musical backgrounds, three of the LSPs also have similar experience.

Several of the participants reported the ability to "visualize music," that is, the ability to look at music and hear it in the mind, or the ability to hear a musical piece and play it ("play by ear"). Acknowledging Harris' conclusions, Robichaux (2000) said this was likely a type of spatial skill.

The researcher found it intriguing that musical ability was a definite similarity among the

HSPs, and it was consistent with portions of the literature. However, two of the LSPs stood out as anomalies in this aspect; both reported the ability to "visualize" when sight-reading music.

Sports Visualization. The last notable area that emerged as a background or experiential theme was one that the researcher was unprepared to recognize. It was the most surprising "find" amidst the discussions of background and experiences, likely because it was something with which the researcher was least familiar.

The literature on spatial ability seems to say little about visualization applied to sports performance. While there are studies that have investigated the relationship between sports involvement and spatial ability (Glassmer & Turner, 1995; Lord & Garrison, 1998; Lunneborg, 1982; Robichaux, 2000), they make little or no mention of visualization for the improvement of performance in particular sports. Nevertheless, several participants reported experiences with visualization that are as vivid, real, and important as any applied task in other subject matters.

Four participants (two HSPs and two LSPs) acknowledged the use of visualization in sports. Additionally, two of the HFGs acknowledged visualization use in sports also. Three acknowledged using visualization in swimming, two acknowledged it in track, while one acknowledged it in tennis. In all cases, the participants acknowledged:

1. *The use of extremely vivid mental imagery*
2. *Representations that included sight, sound, smell, and feeling*
3. *They did the visualization exercises almost daily*
4. *Visualization that positively affected their performance*
5. *Their body would react to their visualization exercises*

The similarities across these cases were surprising because some of the participants were from the LSP group. Plausible explanations for this could have been that some were incorrectly identified as low in spatial ability or that visualization for sports entails the use of a similar, but different mental ability. While the methodology in this study seemed unable to answer the "why," the descriptions provided by these participants seemed to indicate that while they may be low in spatial ability as measured by the MRT or by their performance in the course, they certainly have the mental capacity to visualize, quite vividly and quite readily.

CHARACTERISTICS OF VARYING ABILITY LEVELS

The second area of themes that emerged in this study was related to characteristics that the researcher observed as the participants completed applied problems using a think aloud technique. The researcher called these characteristics, but they may be more aptly called tendencies.

As the participants worked on the applied problems in interview 2, the researcher noted that the HSP and LSP groups seemed to operate similarly, both in their methods of solving the problems, in their communication during the interview, and in certain physical behaviors. Table 2 lists the behaviors that emerged from the analysis of the data.

Table 2.

Characteristics of Participants Based on Spatial Ability Level

Physical Characteristics	
High Visualizers (HSP)	• More verbal while solving problems o Counted Aloud o Types of Comments • Confidence
Low Visualizers (LSP)	• Little narrative while working • Hesitancy/Lack of confidence
Problem-Oriented Characteristics	

High Visualizers (HSP)	• Worked across views • Double-checked frequently
Low Visualizers (LSP)	• Unable to decompose problem

Physical Characteristics. One of the most notable differences between high and low visualizers was the fluidity of their narrative while solving the problems. For the most part, each HSP provided fluid narration of what they were doing or thinking at all times; often they commented why they were doing something and whether they did it often. Some even provided personal anecdotes or self-criticisms. LSPs said very little, even when the researcher prompted them. Initially, the researcher wondered if it was simply a gender difference; because generalizations in the literature often note that females are better in verbal skills (Conner & Serbin, 1985; Fennema & Tartre, 1985; Kimura, 1996; Mann et al., 1990). However, latter interviews with male HSPs continually negated this. The three males and three females in the high ability group exhibited this trait; whereas their counterparts in the low group did not. While this could simply be a manifestation of high verbal ability, it was an observation made during the talk aloud problem solving activities.

Due to their extremely conversational problem solving, two other characteristics appeared in the HSP group. First, the HSPs often made comments that could be classified as self-aware, self-critical, or questioning. Additionally most of the HSPs either counted aloud or said, "I am counting" while they determined measurements on the problems. While the researcher encouraged participants to talk aloud as they worked, he did not highlight that they needed to count aloud. They simply did it on their own. This was something particularly unique to the HSP group.

A final characteristic of the HSP group was the confidence they exhibited. It seemed logical that the HSPs would indeed exude confidence. Overall, most approached the problems in that manner. One could argue that it was the HSPs confidence that resulted in their greater verbalization. However, they were not always confident—particularly when posed with problem 3. In fact, the HSPs vocalized a range of feelings, but overall their body language, communication, and tone presented a steady confidence during the entire problem solving process.

LSP confidence, on the other hand, appeared to be lacking. Often their body language, facial expressions, and tone of voice would enhance statements such as, "And I think I am done with it. Maybe." or "I guess I will [do something]..." For them the spatial experience was full of uncertainty, whereas the HSPs, even when catching a mistake or tackling a complex problem, spoke and acted with relative confidence. A possible future study could investigate this further by examining the relationship between self-confidence and exhibited spatial skill.

Problem-Oriented Characteristics. Aside from the evident physical characteristics, the participants also displayed characteristics relative to the problems they were doing. First, the researcher noticed that the HSPs had the tendency to work across views more frequently. When doing a multiview problem, this manifested itself in them using the views they had already drawn to complete views on which they were working. When creating isometric pictorials, it manifested in them referring to the problem stimulus (and at times drawing directly on it) to compare the provided multiviews.

In comparison, the LSPs did not appear to be working across views. For example, the researcher's observation notes for one participant working on problem 1 acknowledged, "Does not appear to be looking across views very much. Is predominantly looking at the pictorial rather than checking front view on orthographic views. I noticed that earlier interviews students looked back and forth across views a lot." The researcher noted the same thing later in problem 2 when he said, "Participant is not looking at the orthographic views much. Is working on the double angle but not looking at orthographic views." Throughout the LSPs interviews, the researcher noticed repeatedly that they seldom appeared to be working across views.

The second HSP characteristic that emerged was the frequency with which they double-checked themselves. This manifested itself in two different ways. The first was when a participant would get a major portion of a drawing done (e.g., a view in multiview or a feature in a pictorial). He or she would stop and check what had been completed. When drawing multiviews, the HSPs would often compare their solution view to the problem drawing as well as compare their solution views to one another. When drawing a pictorial, the HSPs would compare the isometric version of the feature with the multiviews in the problem stimulus.

The second way this manifested was in real-time, as they were drawing. The problems the participants completed required that they count blocks for measurement. HSPs would count blocks in the problem drawing, draw it out in their solution, and then recount the problem drawing again, and count in their drawing to check it.

Many of the HSPs acknowledged double-checking their work, often doing both types of checking several times for each problem. Again, while the LSPs were not void of checking themselves, they typically only checked themselves at the very end of the problem. It was not evident that they were consistently double-checking (in real time) throughout the problem like the HSPs were.

Aside from their lack of working across views and infrequent double-checking, a common thread amongst the LSPs was their inability to decompose the pictorial drawing problems. Generally, all of the participants were able to do the multiviews. While they frequently forgot lines or features in one or more views, they all were able to solve the overall basis of the problem. However, concerning the pictorial construction, the LSPs seemed to be unable to break the problem down, or decompose it, into simpler geometry in order to solve it. However, most of them, when given alternatives (decomposed pieces from the problem), were able to solve the alternatives.

COMMON ERRORS

One of the common errors made by LSPs was not being able to determine a starting place (visualizing or drawing), assumedly because they could not simplify the object into its component 3D geometries mentally. When given the simplified object, they could then create the pictorial of the simplified object. This conclusion led to a related, but important question as well.

Although all the participants were able (for the most part) to solve the multiview problems, the inability of the LSPs to decompose 3D objects gave rise to the question: how successful were they at decomposing 2D geometries? In reviewing the solutions to problem 1, except for one, all the HSPs either got the entire problem correct or forgot one line (incidentally, the same line). Whereas, all of the LSPs either misaligned the holes (assumed to be a counting error) or forgot a variety of hidden lines associated with hidden features or the oblique surface.

Is it plausible that errors in deconstructing the 2D geometries were the reason for the LSPs missing the hidden lines (or misaligning the holes also)? Or was it that they simply rushed through the problem and did not adequately check themselves? Was there a common decomposition error among the HSPs that caused several of them to forget the exact same line in the exact same view or was it simply coincidence?

The present data cannot answer these questions. To investigate this aspect, future studies should be executed with (1) a series of multiview problems only (of increasing complexity), (2) observation notes that detail the exact order of lines and features drawn by the participants, and (3) questions specifically probing the participant about multiview drawing. Nevertheless, data from this study suggested that LSPs as a group did not have the ability to decompose 3D geometries.

A second common error was indicative of all participants and was related to the creation of pictorial drawings. All participants had difficulty centering the pictorials on the solution grid paper. Many of them acknowledged that they did not know how to do it. Most just guessed, and many that guessed had to erase and start over, finding that the object would not fit on the paper. Others, who got too near completion to erase and start over, just let the object run off the page.

FEELINGS

A final theme that emerged through both ability groups related to feelings they exhibited. HSPs exuded confidence overall, but they also acknowledged a host of other feelings. As the researcher analyzed the data, he wrote in his journal the range of feelings that appeared. They included intrigue, interest, frustration, confusion, indifference, humility, challenge, intimidation, and embarrassment.

What was interesting about these emotions was that nearly every participant experienced each of them. However, the extent to which each participant experienced it was related to his or her ability level. The researcher's initial inclination was that HSPs would likely not experience intimidation or frustration, but on the contrary, they did experience those, just to a smaller degree than the LSPs.

For example, one participant, who appeared to be the strongest in spatial ability overall, acknowledged on problem 3 that he could see how the object could be intimidating (it was designed to be that way due to all of the hidden lines present in the multiviews). However, his intimidation quickly subsided as he began to talk and think through the problem. On the other hand, another participant was intimidated by problem 2 and her intimidation caused her to shut down mentally. While she acknowledged that she had that tendency, it provides an example of the range of "intimidation" experienced by two participants with varying ability levels.

The relevancy of this is to understand that each emotion is a continuum rather than a binary situation. There is a continuum of frustration, intimidation, confidence and the like and all participants experienced some level of each of these emotions when posed with spatial problems. As well, each individual had their own threshold whereby the emotion can either cripple their productivity (in the case if intimidation, frustration, or indifference) or feed it (in the case of intrigue, interest, and confidence).

WHAT IS SPATIAL ABILITY?

In addition to these emergent themes, a major goal of phenomenological research is to provide a holistic description of the phenomenon as experienced by the participants; the group essence of the experience. Based on the descriptions given by participants, the overarching essence of the spatial phenomenon is using the mind to imagine or picture an object, for the purpose of reinterpreting and communicating information about that object in another form (most often, visually). Manifestations of spatial ability are exhibited in either describing anew a pre-existing object or providing visual representations of the object such that others can properly understand the nuances of it.

CONCLUSION

While spatial ability is often described in myriad ways, the nature of this study examined it within the context of engineering drawing, specifically the creation of multiview drawings from isometric pictorials and vice versa. As acknowledged by the participants, within these applied spatial tasks there are two parts to successfully solving them. The first is the ability to spatially interpret the given problem, that is, to understand it. In understanding it, one is required to mentally picture the object, either wholly or in a piecemeal fashion. As the complexity of an object increases, the latter nearly becomes the required and only approach.

When object complexity surpasses the individual mind's capacity to retain it, the observer must decompose the object, imagining only a piece at a time and then, somehow, aggregate the pieces back into the original whole. Therefore, a skill of import in such problems is the ability to decompose the object and imagine mentally-representable chunks of it, without fear or frustration because one cannot see the entirety of the object. This latter point is of importance for stress, anxiety, frustration, and exhaustion seem to counteract the mind's picturing abilities. Nevertheless, critical to the mental representation of complex objects is one's ability to deconstruct complex spatial problems.

The second part of problem solving is the procedural method or process whereby one transfers the mental image to the traditional page. While someone may be able to picture an object in the mind, reproducing it through sketching is a wholly different matter. Many of the participants acknowledged being able to see the object, but questioned their skills for drawing it. All students could sketch the multiviews and all had a process that had been presented in the course for doing so. That many of the participants could not do the pictorials was not surprising. Most acknowledged that they had no process for getting a pictorial representation from their mind to the page.

Qualitative research, and more specifically, phenomenology is a new research approach within the spatial ability domain. The qualitative approach has a long history and is quickly emerging as a viable method for providing scientific knowledge that complements, completes and often enhances traditional quantitative mechanisms.

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