Impacts of Effective Temperature on Sectional View Drawing Ability and Implications for Engineering and Technology Education Students

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Intro

While vision offers distinctive information for the representation of the surroundings, and is crucial for the development of spatial ability, evidence suggests that the lack of visual experience may have limited effects on the perception and mental representation of space (Cattaneo, Vecchi, Coroldi, Mammarella, Bonino, & Ricciardi, 2008 ; Ricciardi, Renzi, Bonino, Kupers, & Pietrini, 2010). Bonino, Ricciardi, Sani, Gentili, Vanello, Guazzelli, Vecchi, & Pietrini (2008) have all stated that visual experience is not a necessary pre-requisite for a functional neural system within the parietal cortex, which is crucial in processing spatial information. Congenitally blind individuals, for example, recruit intraparietal and superior parietal regions during non-visual spatial processing and localization (Weeks, Horwitz, Aziz-Sultan, Tian, Wessinger, Cohen, Hallett, & Rauschecker, 2000), spatial imagery (Vanlierde, De Volder, Wanet-Defalque, Veraart, 2003), orientation discrimination (Ptito, 2005), spatial attention, and memory (Bonino et al., 2008). Individuals could develop their cognitive mechanisms through touch and hearing, which only allows for a sequential processing of information. The Greek philosopher Aristotle, in his thesis *On the Soul*, states that the sense of touch is the most important sense (Bremer, 2008).

> The organ of touch is unique among the senses. In the other senses, the material is neutral with respect to the range in question: the eye jelly, for example, is colorless, the air in the ear silent. Touch, in contrast, inevitably possesses some of the qualities along its own range. (Caston, 2005).
>
> Reid (1764) noted:
>
> . . .by touch we perceive not one quality only, but many, and those of different kinds. The chief of them are heat and cold, hardness and softness, roughness and smoothness, figure, solidity, motion and extension (p.99).

There are two kinds of temperature: ambient temperature and effective temperature. Ambient temperature relates to the surrounding environment and effective temperature to an individual's perception of the ambient temperature (McAndrew, 1993). Temperature can influence thermal comfort, working performance, and social behavior. In a classroom that is slightly cool, an assumption can be made that learning could be affected in a negative way. The purpose of the current study is to identify whether the effective temperature, as related to the sense of touch, can increase or decrease spatial ability performance for engineering technology and technology education students.

The following were the primary research questions:

> Does the difference of effective temperature have an effect on students' spatial visualization ability as measured by the MCT?
>
> Does the difference of effective temperature have an effect on students' ability to sketch a sectional view drawing?

The following hypotheses will be analyzed in an attempt to find a solution to the research question:

> H_0: There is no significant effect on students' sketching ability as measured by the MCT due to a difference of effective temperature.
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> H_1: There is no significant effect on students' spatial visualization ability due to a difference of effective temperature.
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> H_{01}: There is significant effect on students' sketching ability as measured by the MCT due to a difference of effective temperature.
>
> H_{02}: There is significant effect on students' spatial visualization ability due to a difference of effective temperature.

Review of Literature

Spatial ability

Spatial ability can be described as the collection of cognitive skills that permit learners to relate with their environment (Hegarty & Waller, 2005). Spatial cognition acts are the foundation that allow the learner to form and retain mental interpretations of a mental model, or stimulus, in order to rotate or manipulate the object successfully (Carroll, 1993; Höffler, 2010). According to McGee (1979), spatial abilities consist of five distinct areas: spatial perception, spatial visualization, mental rotations, spatial relations, and spatial orientation.

Spatial abilities have long been known as a critical skill for student achievement in STEM-related curriculum and coursework (Pedrosa, Barbero, & Miguel, 2014; Sorby, Nevin, Mageean, Sheridan, & Behan, 2014; Kell & Lubinski, 2013; Cohen & Hegarty, 2012; Metz, Sorby. Berry, Conner, Dison, Allam, Merrill, Peters, Pfister-Altschul, Zhang, & Leach, 2011; Cohen & Hegarty, 2012; Hegarty & Kozhevnikov, 1999). Barke (1993) determined that well-developed spatial skills are critical in the understanding of foundations in chemistry. In addition, Gutiérrez, Domínguez, & González (2015) write that student success depends on well-developed spatial ability in science and engineering. Decades of research have called for a heightened focus on the importance of spatial visualization ability in engineering education (Marunic & Glaza, 2013; Miller & Bertoline, 1991).

Spatial Visualization

A formal definition from McGee (1979) states spatial visualization is "the ability to mentally manipulate, rotate, twist, or invert a pictorially presented stimulus object" (p. 893). Educational research studies conducted in spatial visualization have determined that there may be as many as 84 different career fields where spatial abilities play a critical role in success (Smith, 1964). Maier (1994) found that spatial visualization and mental rotation abilities are particularly important for success in technical professions like engineering. Improving these skills is a key factor in student success and retention in engineering and technology coursework (Ferguson, et al., 2008). In particular, Brus, Zhoa, & Jessop (2004) and Sorby (2001) have produced studies suggesting that there is a positive correlation between spatial visualization ability and the retention and completion of degree requirements for engineering and technology students.

Visual Capacity

While vision offers distinct inputs in spatial representation, individuals lacking vision from birth may often show spatial skills similar to those who do not lack visual capacity (Bonino, Ricciardi, Bernardi, Sani, Gentili, Vecchi,

& Pietrini, 2015). However, these congenitally blind individuals may exhibit impairment in more complex spatial ability tasks as they relate to perspective or angle image. Bonino, et al. (2015) examined the extent to which visual proficiency and sensory modalities affect the functioning of the brain architecture that supports spatial imagery. In the study, both sighted and congenitally blind subjects were measured through brain responses, as it relates to an angle discrimination task using visual, tactile, and auditory stimuli. Both groups did not differ in the tactile stimuli, however, in the blind group performance was impaired in relation to auditory stimuli. These findings suggest that spatial representation relies on a "distributed parietal cortical network that develops and functions independently from visual experience and is able to process non-visual spatial information" (Bonino, et al., 2015, p. 69).

Bonino, et al. (2015) found that blind individuals were less accurate during an auditory task, but during the tactile test these individuals performed similarly to those without visual deficiency. This may be due to a reliance on higher cognitive level processing for non-visual spatial processing (Noordzj, Zuidhoek, & Postma, 2007; Vecchi, 1998). This higher cognitive level processing substantiates that the brain's architecture is pre-programmed to operate independently of visual experience.

Sense of Touch

According to Aristotle, the sense of touch "acts by contact while other senses act from a distance" (cf. *On the soul*, 423b 1-5). Aristotle rejected touch as a sense due to its inherent ability to require contact in order to experience. In addition, since touch is not localized to one particular organ, it must not be considered a "sense" and therefore does not lead us to the belief of a "sixth sense." Ross (1931) stated that color is the object of sight, sound the object of hearing, and flavor the object of taste, but that touch "discriminates more than one set of different qualities" (p.418).

Aristotle and his successors relied on their sources of evidence available at the time. This included theory based solely on phenomenology and gross anatomy. They could relate senses to body parts (e.g. sight ceased to exist when the eyes were closed), but the sense of touch remained elusive (Wade, 2003).

Temperature and Touch

Reid (1764) noted that it is through touch that we experience many qualities, and those of differing kinds. The most dominant of which would be temperature, the sensation of "heat and cold; hardness and softness; roughness and smoothness; figure, solidity, motion, and extension" (p. 99). Erasmus Darwin (1794) supported the qualities of temperature by observing that heat and touch depend primarily on different sets of nerves. From this he determined that the entire muscular system could be considered one organ of sense.

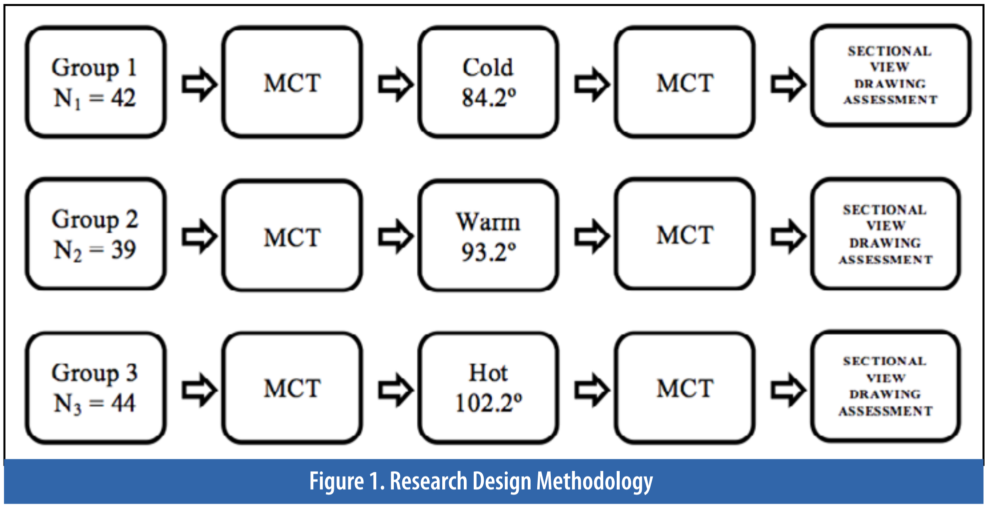


Figure 1. Research Design Methodology

Bell (1803) stated that the sense of touch was the change that arose "in the mind from external bodies applied to the skin" (p. 472). As technology and scientific inquiry advanced, the revelations of skin as an organ became more realistic. In particular, Blix (1884) found that underlying nerves provided stimulation of separate nerve "end-organs in the skin." In addition, Max von Frey (1895) theorized that the sensations of temperature (warm, cold, pressure, and pain) were the responses of "end organs" in the skin. This marked the beginning of defining skin as an organ and identifying phenomenological differences that would lead to the integration of this area into cutaneous anatomy and physiology.

Methodology

A quasi-experimental study was used as a means to perform the comparative analysis of rotational view drawing ability during the Spring of 2016. Using convenience sampling instead of random assignment of the population, made the author believe that a quasi-experimental study was the appropriate methodology to beused. The study compared three groups comprising engineering and technology education students exposed to three different effective temperatures in order to determine whether there is a significant difference in sectional view drawing ability (see Figure 1).

The research protocol was generated and submitted for approval to the College's Human Subjects Review Committee were it was approved and received exempt status. Data was tested for equality of variances using Levene's test. Levene's test indicated equal variances ($F = 3.56$, $p = .382$), therefore degrees freedom did not have to adjust. Temperature data was analyzed by a 3-way repeated measures analysis of variance (ANOVA),with temperature of the stimulus (+84.2°F vs.+ 93.2°F vs.+102.2°F), and the type of stimulus (warm vs. cold vs. hot) as subject factors. The temperature of 93.2°F (temperature of a healthy human's skin) was used as a baseline for the warm water treatment with a variation of + 9F° for hot and -9F° for the cold treatments, respectively.

Tukey's post hoc analyses were performed to account for multiple comparisons and sample size effect. All data was analyzed using SPSS (IBM, Armonk, NY, USA). For the analyses, $p < 0.01$ was used to establish significant differences.

The study was conducted in an engineering graphics course, as part of the Engineering Technology program. The engineering graphics course emphasized hands on practice using 3D drafting software in the computer lab, along with the various methods of editing, manipulation, visualization, and presentation of technical drawings. In addition, the course included the basic principles of engineering drawing/hand sketching, dimensions, and tolerance principles. The participants from the study are shown in Table 1. Using a convenience sample, there was a near equal distribution of the participants between the three groups. The students attending the course during the Spring semester of 2016 were divided into three groups. The three groups ($n1=42$, $n2= 39$ and $n3=44$, with an overall population of $N = 125$) had the same academic background related to engineering graphics coursework (freshman engineering technology and technology education students had to complete the same intro to engineering graphics course the previous semester) were presented with a 3D printed visual representation of an octagonal pyramid (see Figure 2) and were asked to create a sectional view drawing of it.

To generate the three distinct temperature environments, the 3D printed model used for all groups was

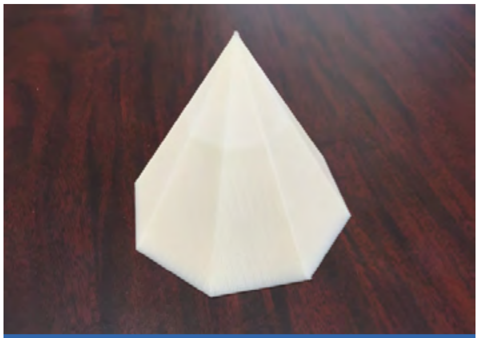


Figure 2. 3D printed Octagonal Pyramid

submerged in water. The use of water did not affect the data collection in any way. This was determined through Filingeri, Redortier, Hodder, & Havenith's 2015 study conducted to identify whether skin wetness is considered a somatosensory experience, resulting from the integration of temperature (particularly cold) and mechanical inputs. It was found that dry and wet stimuli resulted in similar relative increases in local skin temperature. In addition, to eliminate the sense of vision and focus on the sense of touch, the container with water was enclosed in an opaque box. The independent variable in this study was the temperature of the water: 84.2°F, 93.2°F and 102.2°F for the cold, warm, and hot treatments, respectively. Each group member received 60 seconds to "feel" the model in the water. Using only the sense of touch to receive mental data, each student had to create a sectional view of what they felt. This process takes into consideration that research indicates that a learner's visualization ability and level of proficiency can easily be determined through sketching and drawing techniques (Contero, Company, Saorin, & Naya, 2006; Mohler, 1997).

The engineering drawing used in this research was a sectional view of the octagonal pyramid (see Figure 3). Sectional views are very useful engineering graphics tools, especially for parts that have complex interior geometry, as the sections are used to clarify the interior construction of a part that cannot clearly be described by hidden lines in exterior views (Plantenberg, 2013). By taking an imaginary cut through the object and removing a portion, the inside features could be seen more clearly. Students had to mentally discard the unwanted portion of the part and draw the remaining part. The rubric used included the following parts: 1) use of section view labels; 2) use of correct hatching style for cut materials; 3) accurate indication of cutting plane; 4) appropriate use of cutting plane lines; and 5) appropriate drawing of omitted hidden features. The maximum score for the drawing was 6 points.

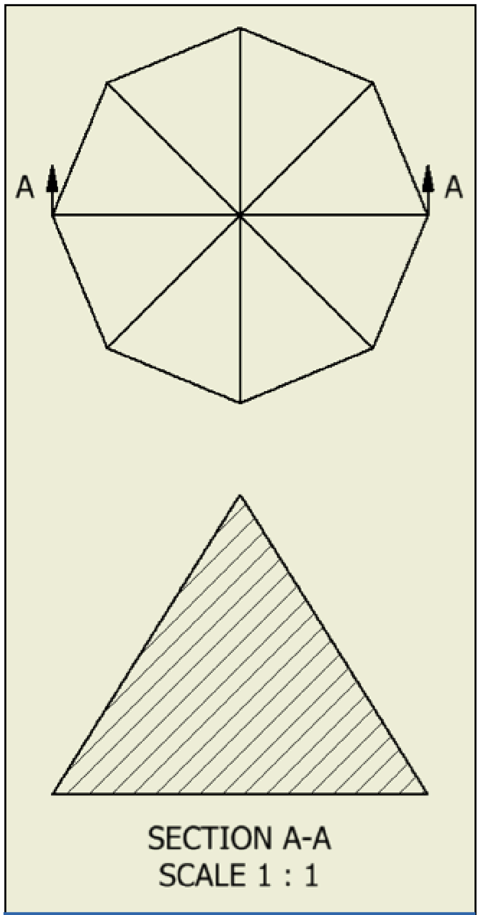


Figure 3. Octagonal Pyramid Sectional View

	N	Mean Pre-test	Mean Post-test	SD	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound
Group 1	42	23.812	23.899	3.0820	0.689	22.492	24.245
Group 2	39	23.637	23.923	2.905	0.602	22.453	24.902
Group 3	44	23.351	23.620	3.086	0.596	22.829	24.701
Total	125	23.600	23.814	3.014	0.629	22.591	24.616

Table 1. MCT pre and post-test Descriptive Results

In addition, all groups were asked to complete the Mental Cutting Test (MCT) (CEEB, 1939) instrument 2 days prior to the completion of the sectional view drawing in order to identify the level of visual ability and show equality between the three groups. The MCT was not used to account for spatial visualization skills in this study. It's only purpose was to establish a near to equal group dynamic based on visual ability, as it relates to Mental Cutting ability. According to Nemeth and Hoffman (2006), the MCT (CEEB, 1939) has been widely used in all age groups, making it a good choice for a well-rounded visual ability test. The Standard MCT consists of 25 problems. The Mental Cutting Test is a sub-set of the CEEB Special Aptitude Test in Spatial Relations, and has also been used by Suzuki (2004) to measure spatial abilities in relation to graphics curricula (Tsutsumi, 2004).

As part of the MCT test, subjects are given a perspective drawing of a test solid, which is to be cut with a hypothetical cutting plane. Subjects are then asked to choose one correct cross section from among 5 alternatives. There are two categories of problems in the test (Tsutsumi, 2004). Those of the first category are called *pattern recognition problems*, in which the correct answer is determined by identifying only the pattern of the section. The others are called *quantity problems*, or *dimension specification problems*, in which the correct answer is determined by identifying, not only the correct pattern, but also the quantity in the section (e.g. the length of the edges or the angles between the edges) (Tsutsumi, 2004).

Data Analysis

Analysis of MCT Scores

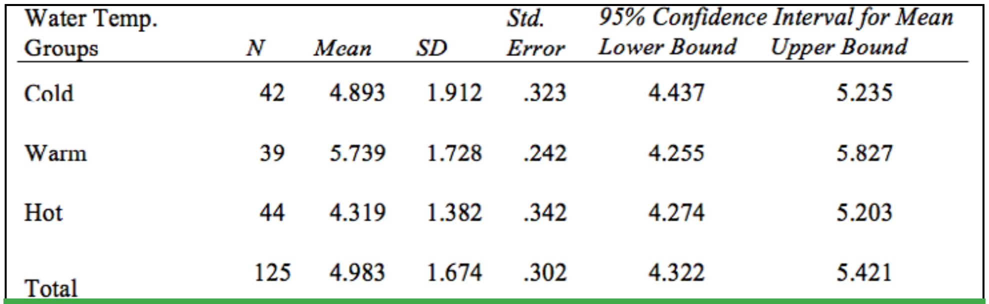
The first method of data collection involved the completion of the MCT instrument prior to the treatment to show equality of spatial ability between the three different groups. The researchers graded the MCT instrument, as described in the guidelines by the MCT creators. A standard paper-pencil MCT pre and post was conducted, in which the subjects were instructed to draw intersecting lines on the surface of a test solid with a green pencil before selecting alternatives. The maximum score that could be received on the MCT was 25. The pre-test results can be seen in Table 1: $n1=23.812$, $n2=23.637$ *and* $n3=23.351$. As far as the post-test, overall means were higher: $n1=23.899$, $n2=23.923$ *and* $n3=23.620$. No noticeable difference was seen for any of the groups that completed the treatment.

In addition, a one-way ANOVA was run to compare group mean and whether they were statistically significantly different during the pre and post treatment, as measured by the MCT. There was no significant difference between the means of the three groups' level of sectional view drawing ability between pre and post treatment, as measured by the MCT instrument F (2, 98) =3.492, p= .310 (see Table 2).

The second method of data collection involved the creation of a sectional view drawing (see Figure. 2). As shown in Table 3, the group that used warm water as part of their treatment ($n=39$) had a mean observation score of 5.739. The groups that used cold water ($n = 42$) and

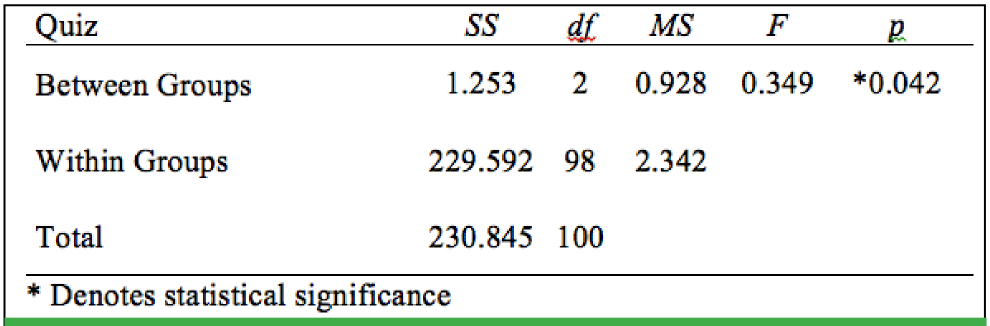
Quiz	*SS*	*df*	*MS*	*F*	*p*
Between Groups	1014.028	2	31.013	3.492	0.310
Within Groups	1003.958	98	4.184		
Total	1108.993	100			

Table 2. MCT pre and post-test ANOVA Results



Water Temp. Groups	N	Mean	SD	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound
Cold	42	4.893	1.912	.323	4.437	5.235
Warm	39	5.739	1.728	.242	4.255	5.827
Hot	44	4.319	1.382	.342	4.274	5.203
Total	125	4.983	1.674	.302	4.322	5.421

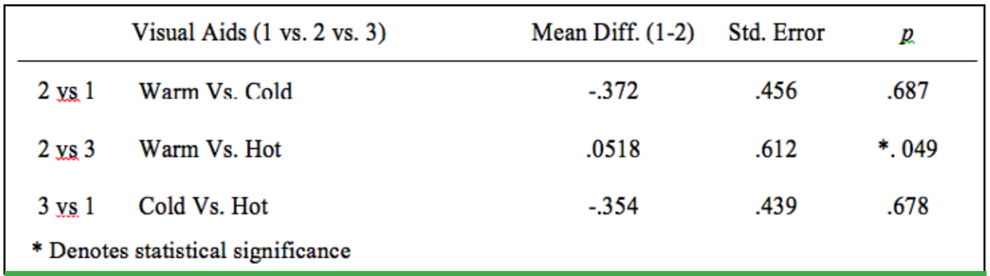
Table 3. Sectional View Drawing Descriptive Results



Quiz	SS	df	MS	F	p
Between Groups	1.253	2	0.928	0.349	*0.042
Within Groups	229.592	98	2.342		
Total	230.845	100			

* Denotes statistical significance

Table 4. Sectional View Drawing ANOVA Results* Denotes statistical significance



Visual Aids (1 vs. 2 vs. 3)		Mean Diff. (1-2)	Std. Error	p
2 vs 1	Warm Vs. Cold	-.372	.456	.687
2 vs 3	Warm Vs. Hot	.0518	.612	*. 049
3 vs 1	Cold Vs. Hot	-.354	.439	.678

* Denotes statistical significance

Table 5. Sectional View Drawing Tukey HSD Results* Denotes statistical significance

hot water (*n* = 44) had lower scores of 4.893 and 4.319, respectively.

A one-way ANOVA was run to compare the mean scores of the graded sketches for significant differences among the three groups. The result of the ANOVA test, as shown in Table 4, was significant: $F(0.349) = 0.042$ $p < 0.05$. The data was dissected further, through the use of a post hoc Tukey's honest significant difference (HSD) test. As can be seen in Table 5, the post hoc analysis showed no statistically significant difference between the Warm Vs. Cold ($p < 0.456$, $d = -.372$), and the Cold Vs. Hot ($p = .439$, $d = -.354$). However, the Warm Vs. Hot ($p = .049$, $d = .612$) showed statistically significant difference.

Discussion

This study was done to determine significant positive effects related to sectional view drawing ability. In particular, the study compared the exposure of engineering technology and technology education students to three different kinds of treatments (different temperatures) and whether a significant difference exists towards sectional view drawing ability.

The null hypothesis that there is no significant effect on students' spatial visualization ability, as measured by the MCT was accepted. However, the second null hypothesis that there is no effect on students' spatial visualization ability to sketch a sectional view drawing due to the difference of effective temperature was rejected due to statistically significant evidence. Students that received treatment using warm water outperformed their peers who received treatment using cold and hot water temperatures, respectively. In a study conducted by Filingeri, et al. (2015), the researchers tried to identify whether the absence of humidity receptors in human skin (the sensitivity of skin wetness) is considered an output resulting from the integration of temperature (warm, hot cold) and mechanical inputs. It was found that warm temperature stimuli have been shown to suppress the perception of skin wetness during initial contact with a wet surface (Filengeri et al., 2015 , p.13). This finding suggests that the temperature of warm water, versus hot and cold, allows the absence of skin wetness perception that could lead to a more direct focus. Based on these findings, it can be assumed that the absence of the skin wetness perception could increase the amount of sensitivity data transferred to the brain that can then be translated into spatial visualization data.

According to Bell (1803/2000), the qualities that we perceive from the sense of touch include hardness, softness, figure, solidity, motion, extension, heat and cold. However, even though heat is a quality, cold is the privation of that quality; therefore, in relation to the body, heat and cold are distinct sensations. An experiment conducted by Johann Wilhelm Ritter (1801) showed that different organs experience heat or cold in a different way. If one brings into contact a zinc pole on the tongue and silver on the gums the sensation was different, as that on the tongue feels very warm and the one on the gums felt cold (p. 458). Based on these findings, an assumption can be made that the sensation received when students were touching the 3D printed model in cold, warm, and hot water was completely different. A different signal for each temperature was received through the sensory qualities that could potentially provide a different message as it relates to spatial visualization abilities. Pfaff (1801) concluded that: "one must consider the sense of temperature (for warmth and cold) as essentially different from the common sense, and as special sense" (p. 10).

Evaluating results in Table 4, the ANOVA test did show a significant difference between the three groups $F(2, 98) = 0.349$, $p < 0.05$ when measuring the sectional view drawing results. A positive difference in the mean of the warm water treatment was observed, and was statistically significant enough to promote a stronger positive correlation. In addition, evaluating results in Table 5, showed statistically significant difference for the Warm Vs. Hot ($p = .049$, $d = .612$) group. As previous studies have suggested the long-term exposure to different temperatures could affect the sensitivity of the skin in a negative way and is likely to affect cognitive abilities. Since cold and hot water temperatures are both reaching more extreme temperatures, it could be suggested that the warm water temperature prolongs the loss of sensitivity and allows for sensitivity of the skin. Due to the fact that the groups in this study were relatively small the results need to be seen with caution and used as the base for additional feature studies. The current paper contributes to understanding the effects of temperature as an instructional tool that can enhance learning.

Limitations and Future Plans

In order to have a more thorough understanding of the effects of temperature, as it relates to spatial visualization ability for engineering technology students, and to add additional information in the body of knowledge, it is imperative to consider further research. Future plans include, but are not limited to:

- Repeating the study to verify the results by using additional types of temperature treatments.
- Repeating the study using a different population,

such as technology education, science, or mathematics students.

- Repeating the study by comparing male versus female engineering technology students.

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