

## **Exploring the Effects of a Visual Thinking Strategies Workshop on the Reflective Thinking of Undergraduate Engineering Students**

### **Dr. Ryan C. Campbell, Texas Tech University**

Having recently completed his Ph.D. through the University of Washington's interdisciplinary Individual Ph.D. Program (see [bit.ly/uwiphd](http://bit.ly/uwiphd)), Ryan is now a Postdoctoral Research Associate at Texas Tech University. He currently facilitates an interdisciplinary project entitled "Developing Reflective Engineers through Artful Methods." His scholarly interests include both teaching and research in engineering education, art in engineering, social justice in engineering, care ethics in engineering, humanitarian engineering, engineering ethics, and computer modeling of electric power and renewable energy systems.

### **Dr. Roman Taraban, Texas Tech University**

Roman Taraban is Professor in the Department of Psychological Sciences at Texas Tech University. He received his Ph.D. in cognitive psychology from Carnegie Mellon University. His interests are in how undergraduate students learn, and especially, in critical thinking and how students draw meaningful connections in traditional college content materials.

### **Dr. Jeong-Hee Kim, Texas Tech University**

Jeong-Hee Kim is Professor of Curriculum Studies and Teacher Education in the Department of Curriculum and Instruction at Texas Tech University. Kim is a curriculum theorist, teacher educator, and narrative inquiry methodologist. Her research centers on various epistemological underpinnings of curriculum studies, particularly engaging in hermeneutical excavation of the stories of students and teachers around the notion of *Bildung*, a human way of developing or cultivating one's capacity. She received the Faculty Excellence in Research/Creative Activities Award from Kansas State University in 2011, and two awards from AERA—Outstanding Narrative Research Article Award in 2009 and Outstanding Narrative Theory Article Award in 2007. She has published numerous articles in top-tier journals including *Journal of Curriculum Studies*, *International Journal of Qualitative Studies in Education*, and *Educational Philosophy and Theory*. In 2015, she published a book on narrative inquiry, *Understanding Narrative Inquiry: The Crafting and Analysis of Stories as Research*, with SAGE publications.

### **Dr. Danny D. Reible P.E., Texas Tech University**

Dr. Danny D. Reible is the Donovan Maddox Distinguished Engineering Chair at Texas Tech University. He was previously the Bettie Margaret Smith Chair of Environmental Health Engineering in the Department of Civil, Architectural and Environmental Engineering and the Director of the Center for Research in Water Resources at the University of Texas in Austin. Dr. Reible holds a Ph.D. in Chemical Engineering from the California Institute of Technology, and is a Board Certified Environmental Engineer, a Professional Engineer (Louisiana), and was elected to the National Academy of Engineering in 2005 for the "development of widely used approaches for the management of contaminated sediments". His research is focused on the fate, transport, and management of contaminants in the environment and the sustainable management of water resources.

### **Dr. Jill Hoffman, Museum of Texas Tech University**

As the Assistant Director for Visitor Experience, and the Helen DeVitt Jones Curator of Education—both for the Museum of Texas Tech University (TTU)—Jill also is a faculty member in the graduate Museum Science program at TTU. Her museum career includes administrative, educational, and outreach experience at various museums, including The Millicent Rogers Museum, Taos, NM; The Museum of New Mexico, Santa Fe; and the Austin Museum of Art, in Texas. She obtained her Ph.D., from The Pennsylvania State University, researching how museums interpret Native American art and culture.

### **Dr. Chongzheng Na, Texas Tech University**

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**Abstract:** Engineering education has long focused on the application of science, math, and technology for solving problems. However, a broad perspective on social issues and interrelated environmental considerations is also needed to address the complex problems of today. The arts and humanities can provide important and often neglected perspectives and help engineers to develop skills for making wise, informed decisions through reflective thinking. In this work-in-progress paper, we contribute to the literature by advancing understanding of the effects of an art-based teaching and learning technique known as Visual Thinking Strategies (VTS), which has not been explored in engineering education to date. In this mixed-methods study, we employed qualitative analyses of writing samples and statistical analyses of survey responses to explore the impact of a VTS training workshop on upper-level environmental engineering students' reflective thinking. The preliminary findings suggest that VTS may help students to become more reflective, more aware of their knowledge of broader contexts, and therefore better able to use that knowledge in developing engineering solutions. Furthermore, our sample of engineering students saw great value in and potential for VTS in engineering education and practice.

## 1. Introduction

The traditional focus of engineering education on technical problem-solving has left little room to develop skills for making wise, informed decisions through reflective thinking. Beyond math, science, and technology, the arts and humanities can provide important and often neglected perspectives for engineers to consider as they wrestle with the complex and interrelated problems of today. In this work-in-progress paper, we contribute to the literature by advancing understanding of the effects of visual art on developing reflective engineers. Indeed, the importance of reflection in engineering is increasingly being recognized in the engineering education community (Sepp et al. 2015). This work also contributes to the engineering education literature on broad thinking (e.g., see Kilgore et al. 2007 and Morozov et al. 2007), contextual competence (e.g., Ro et al. 2015; 2012), as well as addressing the ASEE Multidisciplinary Engineering Division's current call for papers requesting innovative educational approaches that intentionally promote development of professional, non-technical skills. Finally, this work supports ABET and other engineering accreditation programs around the globe (see ABET 2016; ENAEE 2015; IEA 2013), which continue to call for students to understand the impact of engineering solutions in global, economic, environmental, and societal contexts as well as the professional and ethical responsibilities of the engineering profession.

As part of a larger project examining whether and how art and the humanities might help engineers to be more reflective in their work, the goal of the present study is to explore the impact of a Visual Thinking Strategies (VTS) training workshop on engineering students' reflective thinking as revealed through their written observations of art. As a teaching/learning technique created under the collaboration of a cognitive psychologist and a former director of The Museum of Modern Art (see Yenawine 2013 or <http://vtshome.org/about/>), VTS is a group activity led by a facilitator and involves viewing and discussing a piece of visual art. For an effective VTS

session, an image of sufficient detail and character, usually a painting or a photograph, is selected and discussion is initiated by asking the question: “What's going on in this picture?” While the question is simple, choosing a developmentally appropriate image and facilitating a collaborative, engaging, and pedagogically effective discussion session both require careful sensitivity (Hancock 2016; Housen & Yenawine 2011), so training and practice are needed for VTS educators/facilitators (Hailey, Miller, & Yenawine 2015).

VTS was initially designed to help teachers and children better retain information presented at the educational programs of museums, but since its creation a few decades ago it has also proven valuable in other fields. For example, it now finds application in medical and nursing schools to enhance observation and diagnostic skills, as well as in other areas of higher education, such as for communicating science research findings to others (Reilly, Ring, & Duke 2005; Hailey, Miller, & Yenawine 2015; Hancock 2016). However, it appears there has been little use of VTS in engineering education to date, and there are virtually no articles documenting its use in the engineering education literature. This study may well be the first to examine the effects of VTS on engineering students.

In this mixed-methods study, we employ qualitative analyses of writing samples and statistical analyses of survey responses to explore the impact of a VTS workshop on upper-level environmental engineering student’s reflective thinking. The work is motivated by the following research questions:

- 1) In what qualitatively different ways do engineering student observations about art change after learning VTS?
- 2) To what extent might learning VTS change engineering student perceptions of their own contextual competence?

The first research question builds on the idea that writing about an ambiguous visual representation of something (i.e., art) requires one to think about and reflect on the object under observation. In contrast with common notions of reflection in education that focus on explicit attention to the self (e.g., autobiography or journaling), we suggest that writing about art can be considered an implicit form of reflection that draws on one’s individual knowledge and background to generate distinctive perspectives for observation and interpretation. This suggestion is consistent with the philosophy of VTS (though VTS further enables participants to broaden their views through interaction with others).

The second research question builds on the construct of contextual competence developed in the engineering education literature (see Ro et al. 2012 and 2015). It is defined as an “engineer’s ability to anticipate and understand the constraints and impacts of social, cultural, environmental, political, and other contexts on engineering solutions.” Contextual competence is a skill we anticipated VTS might be capable of influencing; while we did not expect to see much change in measures of this construct after a single intervention and over a short time period, we decided to pilot this construct in preparation for a future longitudinal study that involves VTS and other types of exposure to the arts and humanities.

## 2. Methods

### 2.1. Data Collection Procedure

To collect data for our pilot study, we held a 4-hour Saturday VTS workshop for the students at the Museum of Texas Tech University in collaboration with a visiting expert on VTS (the director of the museum from another university). In order to assess participants' initial abilities and perspectives on art, contextual competence, and reflective thinking, we first asked the students to complete a pre-survey and spend 15-minutes experiencing a large mural drawing while writing a short, open-ended essay about what they observed. The students then attended an introductory talk about VTS in a museum classroom and participated in facilitated group discussions of several images shown on screen via a projector. After lunch, the students were divided into two groups for guided walks through some of the museum's galleries to practice facilitating VTS discussions themselves, choosing from among paintings we had pre-selected. To assess the impact of the VTS workshop, the students then wrote two more short, 15-minute essays: one completed in front of the same mural, and another in the museum classroom about a selected photograph depicting a different theme, thus enabling us to explore far-transfer of their VTS learning in future work. Finally, the students completed a post-survey. In this paper, we will present preliminary findings from the ongoing analysis of the essays as well as select items from the pre- and post-surveys.

### 2.2. Instruments

#### Short Essay Prompts

The prompts for short essay at the mural before and after the VTS workshop were identical and read: "Describe what you see in the mural."<sup>\*</sup> The large (17 by 40 foot) mural was painted in black India ink on white plaster and depicted a rural river scene featuring a timber crib dam with rocks, weeds, and large woody debris, as well as numerous smaller details such as a floodgate, ranchers, a crane, horses in field, a grove of trees, and flat-top mountains in the distance. A partial photo of the mural, which captures only some of its detail and little of its magnitude, appears on the artist's website at <http://peterrogersartist.com/r38b.html>.

All essay prompts were accompanied by a statement indicating a desired word length of 200-500 words, requesting that students strive to compose a coherent, organized, and complete essay, and encouraging them not to worry about correct spelling or grammar.

#### Survey Questions

The pre-survey contained 27 items and the post-survey contained 34 items. Both surveys included 4 rating items from Ro et al. (2015) designed to gauge student perceptions of their own contextual competence; these items are given in Table 1. In addition to these questions, both surveys included the same 23 Likert-type questions that asked a variety of questions to gauge perspectives on art interest, the value of art, ambiguity, relationships between art and

<sup>\*</sup> See Section 4.3 (Limitations of the Study) for a discussion of the difference between this prompt and that espoused by the creators of the VTS method as described in the Introduction above.

engineering, problem solving complexity, and creativity. Examples of these 23 survey items are given in Table 2; however, these are provided to the reader primarily for context: responses to most of these questions will not be analyzed in this paper for the sake of brevity. Finally, the questions appearing only in the post-survey are provided in Table 3. All data collection instruments were completed on paper. Clipboards and writing utensils were provided to all students as needed.

Table 1. Contextual Competence Questions from Ro et al. (2015) used in Pre- and Post-Survey

Item #	Question (scale: Excellent / Very Good / Good / Fair / Weak/None)
1	Please rate your knowledge of contexts (social, political, economic, cultural, environmental, ethical, etc.) that might affect the solution to an engineering problem.
2	Please rate your knowledge of the connections between technological solutions and their implications for the society or groups they are intended to benefit.
3	Please rate your ability to use what you know about different cultures, social values, or political systems in developing engineering solutions.
4	Please rate your ability to recognize how different contexts can change a solution.

Table 2. Additional Sample Questions from Pre- and Post-Survey

Item #	Question (scale: Strongly Agree / Agree / Neutral / Disagree / Strongly Disagree)
5	If there is a class session that involves art, I want to attend it.
6	Visual Thinking Strategies (which uses art to develop students' observational skills and critical reasoning) is a valuable teaching and learning tool for engineering students.
7	Art can be useful in helping engineering students to become reflective and ethical.
12	In solving an engineering problem, there is usually one "right" answer.
15	Art can challenge one's thinking.
19	The work of an engineer rarely requires him or her to consider ambiguity.
21	Art and engineering are at opposite ends of the continuum of human knowledge.
22	Creative thought is not useful to engineers.
24	I sometimes feel that my thought processes, as an engineer, are creative.

Table 3. Questions Appearing Only in Post-Survey

Item #	Question (scale: Strongly Agree / Agree / Neutral / Disagree / Strongly Disagree)
28	VTS has a potential to help engineering students develop critical thinking skills necessary in becoming reflective and ethical engineers.
29	I want to continue to learn about VTS.
30	I don't see any value in VTS as a teaching tool in engineering.
-	<b>Question (scale: none)</b>
31	Write any additional thoughts about your experience of taking the VTS workshop here:
32	What is your major?
33	What is your level? FR SO JU SR (Circle one)
34	What is your gender identity? M F (Circle one)

### *2.3. Analysis Methods*

Given the research questions and instruments above, we studied the data using both quantitative and qualitative methods. To address the first research question, we performed an inductive, emergent coding of the pre- and post-VTS essay responses. We first transcribed the hand written data, and then used a qualitative data analysis software program called Quirkos to manage and code the data. In this work-in-progress paper, we report partial, preliminary results of a thematic analysis performed by a single coder and focused on the rhetorical functions served by the writing found in each essay. The rhetorical functions of the writing served to illustrate relative degrees of reflective thinking, as described in Section 3.1 below. Coding was based on units of meaning found in the text and thus applied to passages of variable length including phrases, sentences, and/or paragraphs where appropriate. These codes were not mutually exclusive (i.e., multiple codes may have been applied to separate and/or overlapping passages in each essay). To address the second research question, we used standard statistical methods, in this case descriptive statistics and two-tailed t-tests for correlated samples, to analyze the pre- and post-survey responses from the contextual competence rating scale of Ro et al. (2015).

From these analyses, we expected to gain insights into how well the VTS workshop promoted reflective thinking in undergraduate environmental engineering students. We will use this work as a pilot study to inform our ongoing and future efforts toward a longitudinal study. Indeed, this work is part of a larger curricular effort geared at producing reflective engineers through innovative and transformative curriculum and pedagogy that goes beyond what traditional engineering curricula can offer.

### *2.4. Participants*

The sample population for this pilot study was comprised of upper-level undergraduate students recruited from a large, environmental engineering course at a university in the southwestern United States. This large, public research university is categorized as “Doctoral Universities: Highest Research Activity” by the Carnegie Classification of Institutions of Higher Education (IUCPR, 2016). Students were incentivized to participate in the study with extra-credit to be applied to their course grades by their instructor, who was not a member of the research team.

Thirteen students participated in the pilot study. For comparisons of the essays in this work-in-progress paper, we report a preliminary qualitative analysis of approximately half the participants (n=6) writing. For statistical comparisons of the survey responses, we chose to remove one survey, due to response inconsistency (reverse-coded survey items suggested the participant did not read the questions and simply circled 4 or 5 for all questions), therefore n=12 for comparison of the pre- and post-survey responses. Basic demographics for the participants were collected in the post-surveys and are reported here in Table 4 (rather than in the Findings) for the reader’s convenience.

Table 4. Basic Demographics for Participants (from Post-Surveys)

Demographic		Female	Male	Total
Academic Major	Civil Engineering	2	8	10
	Environmental Engineering	3	0	3
Academic Level	3 <sup>rd</sup> Year (Junior)	2	1	3
	4 <sup>th</sup> Year (Senior)	3	7	10
<b>Total</b>		<b>5</b>	<b>8</b>	<b>13</b>

### 3. Findings

As this is a work-in-progress paper and analysis is ongoing, only partial findings are presented here. Specifically, they are based on (1) a qualitative analysis of about half the participants' pre- and post-VTS essays (n=6), as well as (2) a selection of items from all of the participants' pre- and post-survey responses (n=12).

#### 3.1. Essay Response Analysis Results

Inductive coding of the essays has revealed eight different themes that describe the rhetorical function of the writing: Description, Interpretation, Focus/Point/Meaning, Technique/Style, Outside the Image, Reflects on Previous, Thought/Feeling, and Value. Each of these are summarized in Table 5 and then described and illustrated with quotations below. The rhetorical functions of the writing serve to indicate relative degrees of reflective thinking, with the "Description" theme being the least reflective (directed externally and focused on the art) and the other themes being more reflective across a variety of dimensions. For example, the "Interpretation," "Focus/Point/Meaning" and "Technique/Style" themes, while also externally directed, are more likely to include considerations beyond the art to include the artist. In contrast, the themes of "Reflects on Previous" and "Thought/Feeling" are internally directed to focus on the participants themselves as observers. The "Outside the Image" and "Value" themes reflect an interplay between the internal and external: between the self and the art.

#### Description

Given the focus of the prompt, every essay contained writing that functioned to describe the content observed in the given image. For example, one student (S03) wrote the following in his pre-VTS essay:

*"This mural shows us a landscape ... As for the content of this mural, ...[y]ou see a man in the middle who looks to be working next to some kind of fence in the pond that take[s] water closer to the house in the background."*

#### Interpretation

Like the quote above, most essays also contained writing that functioned to interpret the content in the image. For example, another student (S02) wrote in his pre-VTS essay:

Table 5. Preliminary Results of Inductive Coding of Short Essay Responses Before and After VTS Workshop (n=6)

Theme	Description (writing functions to...)	Direction/ Focus	Total # of Participants		
			Pre-VTS	Post-VTS	Change
Description	describe the content observed	External (art)	6	6	0
Interpretation	interpret the content observed	External (art/artist)	6	5	-1
Focus/Point/ Meaning	suggest a main focus, point, or meaning of the art	External (art/artist)	3	4	1
Technique/ Style	show awareness of the artist's technique or style and/or how it is used	External (art/artist)	2	5	3
Outside the Image	indicate something that is imagined to be outside the image	Int/Ext (self & art)	0	5	5
Reflects on Previous	express reflection on previous thoughts or observations about the art	Internal (self)	NA	3	NA
Thought/ Feeling	indicate how the image made the participant think or feel	Internal (self)	1	2	1
Value	convey the value or worth of the art	Int/Ext (self & art)	0	1	1

*“The dam retains water in an otherwise inhospitable climate, providing sustenance for the worker and his herd.”*

Here, phrases like “inhospitable climate” and “providing sustenance for...” serve as layers of interpretation on the more objective indications of the objects depicted, namely the dam, the water, the human, and the animals. Even simple word choices like “worker and his herd” indicate interpretations that are more subjective, e.g., because the sex of the human in the picture is not necessarily clear, and his or her actions could be interpreted in different ways, such as working to clear the floodgate or even fishing as indicated by another student (S05) who wrote in his post-VTS essay:

*“The man appears to be fishing as he has a rod in the water also suggesting dinner time.”*

Regarding the Interpretation row of Table 5, the reason for its negative change is that one student wrote a very brief response on their post-VTS essay (see the “Reflects on Previous” section below) and did not include any interpretation of the content he observed.

#### Focus/Point/Meaning

About half of the essays contained writing that functioned to suggest a main focus, point, or meaning of the art. For example, S04 indicated in his pre-VTS essay what he thought the overall theme or intent of the mural might be:



*“This mural seems to be showing the peacefulness of the Old West expansion in the United States, but also the emptiness + loniness[sic] someone might have felt when living at that time.”*

Furthermore, in the conclusion of his post-VTS essay, he summarized his understanding of the mural’s objective as:

*“It seems this art isn’t to sway opinion but to show a way of life, due to the amount of detail on the smallest of objects.”*

Other essays were apparently more directed at the art’s focus than its meaning, such as S01 who wrote in his pre-VTS essay:

*“The primary focus of this mural seems to be the dam which is halting river flow.”*

### Technique/Style

Some student writing functioned to show awareness of the artist's technique or style and/or how it was used. For example, several students commented on the striking detail of the mural, such as S03 who wrote the following in his pre-VTS essay:

*“First, you notice the incredible amount of detail that every item has. It is drawn / painted in greyscale. The realism is wonderful. The detail of the objects “closest” to you are highly contrasted, while things in the background seem to fade away giving great realistic perspective.”*

This focused on the technique, expressing an appreciation of it, but later in his post-VTS essay he wrote:

*“This work is very detailed. It draws attention to almost every facite[sic] of the composition... The artist shows that every part brings a valuable dimension to the scene. I believe the artist is trying [to] almost envelope the viewer in the story of the scene.”*

This illustrates an awareness of the impact or effect of the technique while attributing intention to the artist.

### Outside the Image

In their post-VTS writing, most students provided writing that functioned to indicate something outside of the image, such as the viewer, the artist, or some object suggested by the image. An example is provided in S01’s post-VTS essay. When writing about various divisions in emphasis he perceived within the mural, he expanded this perspective to the world outside the mural:

*“There is even a division between the scene in this photo and the world which exists outside of the scene depicted.”*

### Reflects on Previous

About half of the post-VTS essays contained writing that functioned to express reflection on the student's previous thoughts (i.e., during the pre-VTS essay) about the art. For two of these students, they reflected on new perspectives gained, such as S03, who wrote:

*"The things that are drawing my attention now are more detailed..."*

The post-VTS essay of S02, however, began with a brief list of some of the objects he noted in the mural previously, and then went on to state that he did not notice anything new the second time around:

*"I see exactly what I saw before. I remember what I wrote and I can't think of anything new."*

Because of this, S02 wrote a very brief response to the post-VTS essay (see the Interpretation section above). This was the only case of such a response in all 13 participants' essays.

### Thought/Feeling

A few of the students provided writing that functioned to indicate how the art made them think or feel. For S05, his pre-VTS essay suggest that it evoked a pleasant thought:

*"The first thought in looking at the mural is a thought of relaxation and peacefulness. It reminds me of survival, a way of living."*

### Value

One essay provided writing that functioned to convey the value or worth of the art. S04's post-VTS essay read:

*"The detail spent is what makes this artwork what it is + unique to itself."*

To conclude this section, we note that beyond the functions of Description and Interpretation, a number of other types of more reflective student writing were evident. While they were generally less prevalent, they provide evidence of the influence of VTS on engineering student's reflective thinking.

## *3.2. Survey Response Analysis Results*

A preliminary statistical analysis of the pre- and post-VTS survey responses for the Contextual Competence survey items of Ro et al. (2015) is summarized in Table 6. It shows an overall pre to post mean value increase of 0.2 (out of 5) that is very nearly statistically significant ( $p = 0.06$ ) and has a small to moderate effect size of 0.31 (Cohen's  $d$ ). Curiously, only the third of the four individual survey items ("ability to use what you know about different cultures, social values, or political systems in developing engineering solutions") is primarily responsible for this change

with a pre to post mean value increase of 0.42 (out of 5) that is statistically significant ( $p = 0.05$ ) and has a moderate effect size of 0.53 (Cohen's  $d$ ). This can perhaps be explained by the fact that our VTS training workshop did not address issues of knowledge but of ability or skill, and particularly a skill that is enhanced by the kind of reflective thinking that VTS can conceivably help foster. The lack of change in the fourth item (a small, statistically insignificant decrease, in fact) can possibly be explained by noting that the question is rather vague since it relies on recollection of the contexts definition from the first item and drops the term "engineering." The question may not have been understood or it may have been perceived as too non-specific an ability for students to recognize how VTS might help with it. Also, as Ro et al. (2015) reported, it was the item with the lowest factor loading in their confirmatory factor analysis and gave the highest Cronbach's alpha if deleted.

Table 6. Statistics for Responses to Contextual Competence Survey Questions  
( $n=12$ , 5 pt. scale)

Survey Question (from Ro et al. 2015)	Pre-VTS Mean (stdev)	Post-VTS Mean (stdev)	Change in Mean	Effect Size ( $d$ )
Please rate your knowledge of contexts (social, political, economic, cultural, environmental, ethical, etc.) that might affect the solution to an engineering problem.	3.00 (0.95)	3.33 (0.89)	0.33	0.36
Please rate your knowledge of the connections between technological solutions and their implications for the society or groups they are intended to benefit.	3.42 (0.79)	3.58 (0.90)	0.17	0.20
Please rate your ability to use what you know about different cultures, social values, or political systems in developing engineering solutions.	3.08 (0.90)	3.50 (0.67)	0.42**	0.53
Please rate your ability to recognize how different contexts can change a solution.	4.00 (0.95)	3.92 (0.79)	-0.08	0.10
<b>Overall Values</b>	<b>3.38 (0.65)</b>	<b>3.58 (0.70)</b>	<b>0.21*</b>	<b>0.31</b>

\* $p = 0.06$ , \*\* $p = 0.05$  (two-tailed T-tests for correlated samples)

Table 7 provides descriptive statistics for responses to the VTS-related survey questions. These responses clearly suggest that most students had interest and found considerable value in VTS. The first question in the table was asked in both the pre- and post-surveys, but it did not show any meaningful change in value (a non-statistically significant increase of 0.25), likely because we made no attempt to demonstrate or suggest how VTS might be used in engineering education. The other 3 questions were only asked in the post-survey.

Table 7. Descriptive Statistics for Responses to the VTS-related Survey Questions  
(n=12, 5 pt. scale)

Survey Question	Mean (stdev)	Min	Max	Skewness
Visual Thinking Strategies (which uses art to develop students' observational skills and critical reasoning) is a valuable teaching and learning tool for engineering students. (pre- & post-survey)	4.13 (0.68)	3	5	-0.16
VTS has a potential to help engineering students develop critical thinking skills necessary in becoming reflective and ethical engineers. (post-survey)	4.25 (0.75)	3	5	-0.48
I want to continue to learn about VTS. (post-survey)	4.08 (0.90)	3	5	-0.19
I don't see any value in VTS as a teaching tool in engineering. (post-survey)	1.67 (0.65)	1	3	0.44

## 4. Discussion

### 4.1. Essay Results Discussion

Examination of Table 5 shows that one of the effects of the VTS workshop may have been to encourage thinking beyond description and interpretation of the content and thus to be more reflective. Prior to the VTS workshop, no students wrote of anything outside the image in their essays; however in their post-VTS essays, most of them indicated something, such as the artist, themselves, or something only implied in the image. Post-VTS essays also showed more awareness of the artist's technique or style and/or how it was used than the pre-VTS essays. The workshop may have also prompted some students to reflect on their previous thoughts or observations about the art and to notice differences and similarities. Finally, the VTS workshop appears to have prompted a few students to express how the mural image made them think or feel and to convey the value or worth of the art. These qualitative differences illustrate the reflective nature of participation in the VTS workshop. Also, we can report anecdotally that during the small group sessions in the museum galleries, some of the students spontaneously and explicitly recognized the potential value of VTS for engineering practice in such areas as problem scoping in design and to improve listening and feedback in user-centered design scenarios.

### 4.2. Survey Results Discussion

Comparing the values in Table 6 with those reported on page 48 of Ro et al. (2015) for senior engineering students of all majors and across multiple institutions (n = 2,465) shows that the participants in Ro et al.'s study had comparable, though slightly higher mean values (between 3 and 4) as well as lower standard deviations likely due to their much larger sample size. The mean differences and effect sizes between senior engineering students and alumni (n = 1,283) also reported there were similarly comparable, though Ro et al.'s mean differences were somewhat

smaller than ours. Interestingly, the change in mean and effect size values for the third survey item (“ability to use what you know about different cultures, social values, or political systems in developing engineering solutions”) in their comparison of seniors and alumni were the smallest of the four questions, while in our study they were the largest of the four. This suggests that development in this ability is the most lacking in engineering education and our findings may suggest that VTS training could help to improve it, perhaps by increasing self-awareness of knowledge of broader contexts (e.g., culture, values, politics, etc.).

#### 4.3. *Limitations of the Study*

We acknowledge here several limitations of our study. First, we recognize the small sample sizes of this pilot study and its lack of a control group. Generalizations based on these findings should be made judiciously: perhaps best viewed as *moderatum* generalizations that limit both the scope of the claims and the degree to which they are held (Williams 2000; Payne and Williams 2005).

Second, we recognize that the students self-selected to participate in this experiment, so these findings could reflect the perspectives of a relatively small subset of engineering students who are inclined toward art and reflection. This assertion is somewhat supported by the survey results for questions 5 and 8, which asked about interest in attending classes involving art and the museum, respectively; pre-VTS responses for both questions averaged 3.7 out of 5 (standard deviations equal to 1.1 and 0.78, respectively) with lows of 2, highs of 5, and negative skewness (-0.26 and -0.67, respectively). However, when we later asked a different group of students from the same class who attended a similar Saturday exercise about moral dilemmas, they almost unanimously said the topic had nothing to do with their decision to participate, but that the date worked well for them and they wanted extra credit. Therefore, we can only speculate on the effects of self-selection bias until more data is collected and analyzed.

Finally, we acknowledge here the difference between the prompt used in this research (“Describe what you see in the mural”) and that espoused by the VTS method (“What's going on in this picture?”). It is likely that the prompt we used inclined participants to write responses that were more descriptive of what they saw rather than to interpret or make meaning of it. For the purpose of assessing the impact of the VTS workshop, the prompt we used generated data showing qualitative differences that may have been harder to distinguish using the canonical VTS prompt, which solicits perceptions of activity rather than description. We will explore this difference further in future work.

### 5. **Conclusions**

In this paper, we presented preliminary findings from an ongoing, mixed methods study exploring the impact of an innovative and art-based educational activity on engineering students’ thinking. The activity, a 4-hour Visual Thinking Strategies (VTS) training workshop, was intended to help students to better recognize and appreciate details in art, and to think more deeply about the meanings and possible implications of other works in the museum. We viewed this as a first step toward developing skills of reflection that may eventually transfer to

engineering thinking and doing, and our findings here provide evidence that supports that hypothesis. The findings suggest VTS may indeed help engineering students to become more reflective, more aware of their knowledge of broader contexts like culture, values, or politics, and therefore better able to use that knowledge in developing engineering solutions. Furthermore, our sample of engineering students saw great value in and potential for VTS in engineering education and practice.

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