Learning Strategy and Verbal-Visual Preferences for Mechanical Engineering Students

Dr. Charles E. Baukal Jr. P.E., John Zink Hamworthy Combustion

Chuck Baukal, Ph.D., P.E. is the Director of the John Zink Institute, which is the training organization for John Zink Hamworthy Combustion where he has been since 1998. He has over 30 years of industrial experience and over 20 years of adjunct teaching experience. He is currently an adjunct instructor at Oral Roberts University, the University of Tulsa, the University of Oklahoma, and the University of Utah. He is the author/editor of 13 books on industrial combustion and over 150 publications on combustion and engineering education, and an inventor on 11 U.S. patents.

Dr. Lynna J. Ausburn, Oklahoma State University

Dr. Ausburn is Professor of Occupational Education in the College of Education at Oklahoma State University. She teaches courses in quantative research, theory in research, visual design, and adult education. Her research interests include virtual reality environments for learning, virtual HRD, and adult learning strategies and styles. She has worked in 19 countries in the field of workforce and productivity development.

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Abstract

The learner characteristics of preferred learning strategy and verbal-visual preferences of 59 mechanical engineering students at two Midwestern universities were studied in relation to the demographics of gender, age range, class in school, ethnicity, native country, and native language. Learning strategy and verbal-visual preferences were measured with the ATLAS and the Verbal-Visual Learning Style Rating instruments, respectively. Neither characteristic had been previously measured for mechanical engineering students. The overall learning strategy preference profile for the mechanical engineering students was 31.5% Navigators, 35.2% Problem Solvers, and 33.3% Engagers. This profile was not statistically significantly different from the established values for the general population. Because mechanical engineering students appear to be approximately equally divided among the three learning strategy preferences, a variety of instructional techniques addressing all three styles is recommended for use by instructors to match students' preferences. The overall verbal-visual preference profile was 6.8% more verbal, 49.2% no strong preference, and 44.1% more visual. This profile is statistically significantly different than the general population and suggests mechanical engineering instructors should design highly visual instructional materials. This paper reports on the relationships found between learner characteristics and demographics. It also includes recommendations for instructional practice and future research.

Introduction

There continue to be calls for improving engineering education. The U.S. National Academy of Engineering established a Committee on Engineering Education to answer the question "What will or should engineering be like in 2020?"[1] The Phase 2 report from that committee titled *Educating the Engineer of 2020*[2] calls for the reinvention of engineering education. An important finding of that study was the importance of addressing how students learn in addition to what they learn and recommended more research into engineering education. This included how to better serve students with different learning styles and how to determine pedagogical approaches that excite them. The *Journal of Engineering Education* recommended further research on how engineering learners' develop knowledge.[3] Duderstad recommended (p. v) "a systematic, research-based approach to innovation and continuous improvement of engineering education."[4] The U.S. National Academy of Engineering identified 14 grand challenges in engineering.[5] One of those challenges is to advance personalized learning that recognizes individual preferences and aptitudes to help motivate learners to become more self-directed. While that challenge was targeted at the development of learning software by computer engineers, it applies to all types of learning and learners, including engineering students.

The purpose of this study was to address the current lack of information about learning strategy and verbal-visual preferences of mechanical engineering students by determining those preferences for a sample of those students. The following research questions were considered: (1) What are the learning strategy and verbal-visual preference profiles for mechanical engineering students?, (2) How do the learning strategy and verbal-visual preferences of mechanical engineering students compare to the established norms for the general population?, and (3) What are the relationships of mechanical engineering students' learning strategy and verbal-visual preferences to the demographic variables of gender, age range, class in school, ethnicity, native country, and native language?

Learner Preferences

Learning Strategy Preference

One way to address individual differences in how students learn and to personalize learning options is through the concept of learning style. *Learning style* (also referred to as *psychological type*[6,7]) refers to how students preferentially perceive (e.g., sensory vs. intuitive), how information is most effectively perceived (e.g., verbally or visually), how information is preferentially organized (e.g., inductive vs. deductive), how information is processed (e.g., actively vs. reflectively), and how understanding progresses (e.g., sequentially vs. globally).[8] These styles are relatively stable and concern cognitive, affective and psychological behaviors about how learners perceive, interact with, and respond to a learning environment.[9] Numerous previous studies have considered learning styles for engineering students. One example is a study of a small sample of engineering students at the University of Texas.[10] In that study, Kolb's Learning Style Inventory (LSI)[11] consisting of four learning styles (convergent, divergent, assimilation, and accommodation)[12] was used to determine the students' learning styles. The overwhelming majority was almost equally split between convergers (learning style characterized by problem solving, decision-making, and practical application of ideas) and assimilators (learning style characterized by inductive reasoning and the ability to create theoretical models). Another example study was done at the University of Cincinnati under a grant from the U.S. National Science Foundation.[13] Again, most engineering students were found to be assimilators or convergers. This was comparable to other studies that found the learning styles of engineering students were statistically significantly different than the learning styles of the general population. Another example study using Kolb's LSI to determine the learning styles of engineering students at Atilim University in Turkey found that assimilators were predominant.[14] In another study that also used Kolb's LSI, engineering students at Morgan State University were predominantly assimilators.[15] Larkin-Hein and Budny gave specific instructional design recommendations for each type of learning style for engineering students.[16] However, Holvikivi argued that despite its popularity, the use of learning styles testing in engineering education is poorly understood.[17] Another problem with learning styles is that they have been defined and tested in a variety of ways which makes it difficult to compare studies and generalize results.[18]

A potentially beneficial alternative to the standard definitions and assessments for learning styles is known as *learning strategies*. *Learning strategy preferences*, like traditional learning styles, are important characteristics that vary among learners. Conti and Fellenz (1991, p. 1) defined learning strategies as "techniques or skills that an individual elects to use in order to accomplish a learning task."[19] Learning styles are believed to be stable and deeply ingrained processes for processing information.[20,21] In contrast, learning strategies are believed to be less rigid and are more related to personal preferences and choices made by learners during learning tasks.[22-24] Learning strategy preference is a potentially important learner variable[25] that could be used by instructors to enhance students' learning experiences.[18] Learning strategy preferences were not found to have been previously measured for engineering students.

Through a complex and lengthy process, Conti and his associates developed and validated the instrument known as ***A***ssessing ***T***he ***L***earning Strategies of ***A***dult***S*** or ATLAS. An important advantage of this instrument is that it is simple to administer and is currently the generally-accepted method for measuring learning strategy preferences.[18] Three distinct learning strategy groups were identified: Navigators, Problem Solvers, and Engagers.[26] *Navigators* plan their learning and focus on completing the necessary activities to achieve their goals. Order and structure are important to these learners, who tend to be logical, objective, and perfectionists. They want clear objectives and expectations at the beginning of a course and in advance of activities, such as in an explicit and detailed syllabus. *Problem Solvers* are critical thinkers who like to explore multiple alternatives. For them, the process is important so they need flexibility in completing learning activities. They may have difficulty making decisions because they have to make a choice among multiple alternatives and because the exploration process which they enjoy must come to an end. This may cause them to appear to procrastinate in making decisions because they do not want the process to end. *Engagers* are more affective learners who enjoy learning they perceive to be fun or personally beneficial. They are interested in building relationships with both teachers and fellow students during learning, which means they typically enjoy group activities. The emotional aspect of learning is important to Engagers. The distribution of the three ATLAS strategy preferences in the general population is relatively evenly distributed: 36.5% Navigators, 31.7% Problem Solvers, and 31.8% Engagers.[26]

Different professions may have different learning strategy preference profiles. For example, Birzer and Nolan (2002) found that law enforcement had a distinctive profile compared to the general population in a comparison of known population norms to the preferred learning strategies of urban police in a Midwestern city.[27] They found there were some differences between those working in community policing environments and those who did not. Police involved in community policing tended to be Problem Solvers. Ausburn and Brown (2006) studied career and technical education students and found that most were Engagers.[28] To date there have not been any studies to determine the ATLAS-defined learning strategy preferences of engineers, the occupational group of interest here.

Verbal-Visual Preference

A major dimension of cognitive style is the verbalizer-visualizer dimension.[29,30] Unfortunately, there is no consensus on terminology for this dimension as it has been called a cognitive style, a learning style, and a learning preference.[31] "Visualizers tend to think more concretely, use imagery, and personalize information. While learning they prefer graphs, diagrams, or pictures added to text-based material. Verbalizers prefer to process information from words, either by reading or listening, rather than through images" (Jonassen & Grabowski, p. 191).[32] Learners who have no strong preference for either verbal or visual processing are referred to as *flexible stylists*, also called *bimodal* or *mixed processors*.[33] More visual learners may approach learning tasks with visual learning strategies, while more verbal learners may use more verbal strategies.[34] When given a choice, verbalizers tend to select more verbal content and visualizers tend to select more visual content.[35]

Many instruments have been developed to measure this cognitive style. Richardson (1977) developed a 15-item questionnaire called VVQ (verbal and visual questions).[36] His research showed 15 to 25% of people tested fell into what he called either habitual verbalizers or habitual visualizers, with the balance in between. He recommended using 15% verbalizers and 15% visualizers with the balance in between for research purposes. Felder and Silverman (1988) wrote a highly cited paper on learning and teaching styles in engineering education.[8] One of the five dimensions they discussed included visual-auditory. An instrument was developed that is a self-scoring 44-item questionnaire called the Index of Learning Styles (ILS).[37] Montgomery (1995) used the ILS instrument to sample the learning styles of 143 students in an introductory sophomore-level chemical engineering class.[38] She found that 69% were visual and 30% were verbal (1% were reported as None). Multimedia software was developed for the course, in part because multimedia software favors visual learners which were the overwhelming majority of the students. Rosati (1999) used the ILS to sample a large group (*N* = 858) of engineering students at the University of Western Ontario and found that 80% were visual (89% of males were visual, 69% of females).[39] The verbal-visual preference of the balance of the 20% of the participants was not reported. Kirkham, Farkas, and Lidstrom (2006) found that 85% of the University of Washington engineering students taking a particular class were visual as determined using the ILS.[40] The verbal-visual preference of the balance of the 15% of the participants was not reported.

The verbalizer-visualizer preference, as measured by the Verbal-Visual Learning Style Rating (VVLSR) established by Mayer and Massa (2003), represents the *perceptual cognitive aspect of adult learning styles*.[41] This instrument was validated against a number of other instruments and was used here because of its simplicity (a single question). It was used in this study to examine possible relationships between perceptual/cognitive learning preferences and demographics.

Methodology

This study used a quantitative descriptive design based on survey methodology, which uses instruments such as questionnaires to collect information from one or more groups of subjects.[42] In the fall 2012 and spring 2013 semesters, a total of 195 engineering students from two Midwestern private universities were sampled to determine their learning strategy preferences and verbal-visual cognitive styles. Three instruments were used in that study: a demographics questionnaire, ATLAS, and the VVLSR. The demographics questionnaire was used to collect information such as gender, age range, year in college, major, ethnicity, native language, and native country. The results of only the learning strategy preferences for all engineering majors are reported elsewhere.[43] Of that sample, 59 were mechanical engineering students. They are the subjects of interest here. The surveys were completely voluntary and anonymous. The sample from University A was representative of the entire population as the data were collected during an engineering seminar course required of all engineering students. The sample from University B was not representative of the population where cluster sampling was done during a monthly meeting of chemical engineering students and during a thermodynamics course required for most engineering majors.

Table 1 shows the gender and age distributions of the sample. Females represented 15% and males 85% of the total sample. Most (65%) of the respondents were 20 years old or younger.

Table 1 Distribution of sample by gender and age ($N = 59$).

	University A		University B		Total	
	n	%	*n*	%	*n*	%
Gender						
Female	7	13.2	2	33.3	9	15.3
Male	46	86.8	4	66.7	50	84.7
Total	53	100.0	6	100.0	59	100.0
Age Range						
17-18	14	26.4	0	0.0	14	23.7
19-20	21	39.6	3	50.0	24	40.7
21-22	14	26.4	3	50.0	17	28.8
23+	4	7.5	0	0.0	4	6.8
Total	53	100.0	6	100.0	59	100.0

Table 2 shows the class in school for the respondents. The highest proportion of the subjects was freshmen and the lowest was sophomores and seniors.

Table 2 Distribution of subjects by class in school ($N = 59$).

	University A		University B		Total	
Class in School	*n*	%	*n*	%	*n*	%
Freshman	22	41.5	0	0.0	22	37.3
Sophomore	6	11.3	5	83.3	11	18.6
Junior	15	28.3	0	0.0	15	25.4
Senior	10	18.9	1	16.7	11	18.6
Total	53	100.0	6	100.0	59	100.0

Table 3 gives some cultural information about the respondents including ethnicity, native country, and native language. Most were Caucasian/White with Other/Multiple and Hispanic/Latino the next most reported. In the Other/Multiple category, of those that specified, students reported (2) Native American and (4) Middle Eastern. One student did not report their Other/Multiple ethnicity. The vast majority of the students were born in the U.S.A. In the Other category, students reported native countries of (1) Columbia, (1) Mexico, (1) Russia, (4) Saudi Arabia, and (2) Zimbabwe. For the vast majority of the students, English was their primary language. In the Other language category, of those that specified, students reported (4) Arabic, (1) Shona, and (2) Spanish.

Table 3 Respondents' cultural attributes (ethnicity, native country, and native language) ($N = 59$).

	University A		University B		Total	
	n	%	*n*	%	*n*	%
Ethnicity						
African American	4	7.5	1	16.7	5	8.5
Asian	2	3.8	1	16.7	3	5.1
Caucasian/White	36	67.9	0	0.0	36	61.0
Hispanic/Latino	6	11.3	0	0.0	6	10.2
Other/Multiple	5	9.4	4	66.7	9	15.3
Total	53	100.0	6	100.0	59	100.0
Native Country						
U.S.A.	47	88.7	2	33.3	49	83.1
Other	6	11.3	4	66.7	10	16.9
Total	53	100.0	6	100.0	59	100.0
Native Language						
English	49	92.5	2	33.3	51	86.4
Other	4	7.5	4	66.7	8	13.6
Total	53	100.0	6	100.0	59	100.0

Results and Discussion

Learning Strategy Preference

Table 4 shows a comparison of learning strategy preferences by subject type. Conti compiled a large database of 3070 subjects from 36 dissertations using the ATLAS instrument.[26] Birzer and Nolan specifically sampled police officers from a particular police force.[27] The percentages of mechanical engineering students who were Navigators and Problem Solvers fell between the large sample, referred to here as the General Population, and the police officers. The percentage of mechanical engineering students who were Engagers was similar to the General Population sample, both of which were larger than for the police sample. A one sample chi-square analysis of the learning strategies for engineering students assuming the expected frequencies equal to that for the general population did not present a statistically significant difference at the 95% confidence level for the learning strategy preferences of the mechanical engineering students ($\chi^2 = 0.744$, $df = 2$, $p = 0.689$).

Table 4 Learning strategy preference by subject type.

Learning Strategy Preference	General Population (Conti, 2009)		Law Enforcement (Birzer and Nolan, 2002)		ME Students (this study)	
	n	%	*n*	%	*n*	%
Navigator	1121	36.5%	19	23.8%	17	31.5
Problem Solver	973	31.7%	40	50.0%	19	35.2
Engager	976	31.8%	21	26.3%	18	33.3
Missing					5	8.5
Total	3070	100%	80	100%	59	100.0

Table 5 shows a comparison of the distribution of learning strategy preferences by institution. A Pearson chi-square analysis of the University A data compared to the general population (χ^2 = 0.356, $df = 2$, $p = 0.837$) did not present a statistically significant difference for learning strategy preferences. There were not enough participants from University B for a valid statistical analysis.

Table 5 Learning strategy preference by institution ($N = 59$).

Learning Strategy Preference	University A		University B		Total	
	n	%	*n*	%	*n*	%
Navigator	16	30.2	1	16.7	17	28.8
Problem Solver	16	30.2	3	50.0	19	32.2
Engager	16	30.2	2	33.3	18	30.5
Missing	5	9.4	0	0.0	5	8.5
Total	53	100.0	6	100.0	59	100.0

Table 6 shows learning strategy preference by gender for this study. There was no statistically significant difference ($\chi^2 = 0.535$, $df = 2$, $p = 0.765$) in the distribution of learning strategy preferences for males compared to the general population. There were not enough female participants for a valid statistical comparison to the males or to the general population.

Table 6 Learning strategy preference by gender (N = 59).

Learning Strategy Preference	Female		Male		Total	
	n	%	*n*	%	*n*	%
Navigator	2	22.2	15	30.0	17	28.8
Problem Solver	2	22.2	17	34.0	19	32.2
Engager	4	44.4	14	28.0	18	30.5
Missing	1	11.1	4	8.0	5	8.5
Total	9	100.0	50	100.0	59	100.0

Table 7 shows a comparison of learning strategy distributions by ethnicity. There were only enough participants in the Caucasian/Whites category for a statistical analysis. No statistically significant difference ($\chi^2 = 0.697$, $df = 2$, $p = 0.706$) was found for that category compared to the general population.

Table 7 Learning strategy preference by ethnicity (N = 59).

Ethnicity	Navigator		Problem Solver		Engager		Missing		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
African American	1	5.9	0	.0	2	11.1	2	40.0	3	5.1
Asian	1	5.9	0	.0	1	5.6	2	40.0	2	3.4
Caucasian/White	10	58.8	13	68.4	11	61.1	1	20.0	34	57.6
Hispanic/Latino	1	5.9	2	10.5	3	16.7	0	0.0	6	10.2
Other	3	17.6	3	15.8	1	5.6	0	0.0	7	11.9
Multiple	1	5.9	1	5.3	0	0.0	0	0.0	2	3.4
Total	17	100.0	19	100.0	18	100.0	5	100.0	59	100.0

Table 8 shows a comparison of learning strategy distributions by native country and native language. No statistically significant difference ($\chi^2 = 0.027$, $df = 2$, $p = 0.987$) was found for those born in the U.S.A. compared to the general population. There were not enough participants born outside the U.S.A. for a valid statistical analysis. There was no statistically significant difference ($\chi^2 = 0.241$, $df = 2$, $p = 0.886$) for those whose native language was English compared to the general population. There were not enough participants whose native language was not English for a valid statistical analysis.

Table 8 Learning strategy preference by native country and native language ($N = 59$).

	Navigator		Problem Solver		Engager		Missing		Total	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Native Country										
U.S.A.	16	94.1	15	78.9	14	77.8	4	80.0	49	83.1
Other	1	5.9	4	21.1	4	22.2	1	20.0	10	16.9
Total	17	100.0	19	100.0	18	100.0	5	100.0	59	100.0
Native Language										
English	16	94.1	15	78.9	16	88.9	4	80.0	51	86.4
Other	1	5.9	4	21.1	2	11.1	1	20.0	8	13.6
Total	17	100.0	19	100.0	18	100.0	5	100.0	59	100.0

Felder and Silverman (1988) recommended that teachers use instructional techniques to address a range of learning styles for engineering students to enhance learning.[8] Rutz and Westheider (2006) recommended that teachers use a variety of instructional methods to engage all learners.[13] Because the learning strategy preference profile measured in this study was approximately evenly distributed among the three preference categories, it is recommended that instructors use a variety of instructional techniques to meet the entire range of student preferences.

<u>Verbal-Visual Preference</u>

Table 9 shows a comparison of the distribution of verbal-visual preferences by institution. There were not enough ME students at University B to compare the profiles of both universities to each other. A chi-square analysis of the data from both universities compared to Richardson's (1977) profile for the general population ($\chi^2 = 38.401$, $df = 2$, $p = 0.000$) showed the ME students were strongly statistically different. Similarly, the ME students' profile was strongly statistically different than Rosati's profile ($\chi^2 = 799.789$, $df = 2$, $p = 0.000$). That could be due to the limited number of categories reported by Rosati (visual or not visual). If the Bimodal and Visual categories in the present study were combined, the distribution would be much closer to Rosati's.

Table 9 Verbal-visual preference by institution ($N = 59$).

Gender	University A		University B		Total	
	n	%	*n*	%	*n*	%
Verbal	3	5.7	1	16.7	4	6.8
Bimodal	24	45.3	5	83.3	29	49.2
Visual	26	49.1	0	0.0	26	44.1
Total	53	100.0	6	100.0	59	100.0

Table 10 shows the verbal-visual preferences by gender for this study. There were not enough female participants to compare against the males. There was a strong statistical difference in the distribution of verbal-visual preferences of males compared to Richardson's ($\chi^2 = 33.124$, $df = 2$, $p = 0.000$) and Montgomery's ($\chi^2 = 1117.096$, $df = 2$, $p = 0.000$) profiles.

Table 10 Verbal-visual preference by gender ($N = 59$).

Learning Strategy Preference	Female		Male		Total	
	n	%	*n*	%	*n*	%
Verbal	0	0.0	4	8.0	4	6.8
Bimodal	5	55.6	24	48.0	29	49.2
Visual	4	44.4	22	44.0	26	44.1
Total	9	100.0	50	100.0	59	100.0

Table 11 shows a comparison of the verbal-visual preference distributions by ethnicity. The only group with enough participants for a valid statistical analysis was the Caucasian/White group which was strongly statistically different than Richardson's ($\chi^2 = 25.005$, $df = 2$, $p = 0.000$) and Montgomery's ($\chi^2 = 874.676$, $df = 2$, $p = 0.000$) profiles.

Table 11 Verbal-visual preference by ethnicity ($N = 59$).

Ethnicity	Verbal		Bimodal		Visual		Total	
	n	%	*n*	%	*n*	%	*n*	%
African American	1	25.0	3	10.3	1	3.8	5	8.5
Asian	0	0.0	1	3.4	2	7.7	3	5.1
Caucasian/White	2	50.0	18	62.1	16	61.5	36	61.0
Hispanic/Latino	0	0.0	2	6.9	4	15.4	6	10.2
Other	1	25.0	4	13.8	2	7.7	7	11.9
Multiple	0	0.0	1	3.4	1	3.8	2	3.4
Total	4	100.0	29	100.0	26	100.0	59	100.0

Table 12 shows a comparison of verbal-visual distributions by native country and native language. There were not enough participants whose native country was not the U.S.A. and whose native language was not English. There was a strongly statistically different difference for those MEs born in the U.S. compared to Richardson's ($\chi^2 = 45.334$, $df = 2$, $p = 0.000$) and Montgomery's ($\chi^2 = 1047.900$, $df = 2$, $p = 0.000$) profiles. The profile for those ME students whose native language was English was strongly statistically different than Richardson's ($\chi^2 = 42.324$, $df = 2$, $p = 0.000$) and Montgomery's ($\chi^2 = 1191.120$, $df = 2$, $p = 0.000$) profiles.

Table 12 Verbal-visual preference by native country and native language ($N = 59$).

	Verbal		Bimodal		Visual		Total	
	n	%	*n*	%	*n*	%	*n*	%
Native Country								
U.S.A.	2	50.0	23	79.3	24	92.3	49	83.1
Other	2	50.0	6	20.7	2	7.7	10	16.9
Total	4	100.0	29	100.0	26	100.0	59	100.0
Native Language								
English	2	50.0	25	86.2	24	92.3	51	86.4
Other	2	50.0	4	13.8	2	7.7	8	13.6
Total	4	100.0	29	100.0	26	100.0	59	100.0

Based on the visual-verbal preference profile measured in this study, ME students were found to be highly visual. This suggests instructional content should be highly visual.

Conclusions and Recommendations

The overall learning strategy preference profile for mechanical engineering students was not statistically significantly different from the established general population norms. Conti reported that no statistically significant differences were found to be associated with any demographic variables such as gender or race.[26] Similarly for this study, no relationship was found between learning strategy preferences and gender. The verbal-visual preference for mechanical engineering students was statistically significantly different than the general population. ME students are much more visually-oriented compared to the general population.

The results of this study have implications for the instructional strategies used to teach engineering students or the *how* to teach and not *what* to teach. This study suggests that a range of techniques should be used as the ME students were comparably divided among the three learning strategy preferences. Instructional content should be highly visual which is the preferred verbal-visual style for ME students. Instructors must be careful not to disproportionately design instructional materials and methods for their own learning strategy and verbal-visual preferences and instead should use a variety of techniques to address the preferences of all students.

Instructors should consider administering the ATLAS instrument at the beginning of a course, both to find out the learning strategy profile of those enrolled in the class and so the students themselves find out their own preference and understand the other preferences. It may be helpful to discuss at the beginning of a course that activities targeted for one learning strategy preference may be less than desirable for those students with other preferences. For example, Navigators prefer more efficient activities (e.g., the instructor directly gives them the answer) while Problem Solvers prefer to explore solutions on their own. Another example is that Navigators often prefer to work by themselves because they have more control over the process, whereas Engagers prefer to work in groups because of the interaction.

Since ME students will normally go into the workforce after graduation, they need to be prepared to work with people having all three learning strategy preferences. While they may not themselves prefer certain types of activities, they should at least be able to tolerate them as they may have to experience them in the work environment. Through knowledge of the learning strategies concept and the ATLAS instrument, it may be possible to improve instructional practice in engineering education and to better prepare MEs to engage effectively with their colleagues in the classroom and later in the workplace. Increasing visual learning content should be more effective in helping ME students learn new content.

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