Engineering Students' Learning Strategy Preferences

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Abstract

The learning strategy preferences, as measured by the ATLAS test, of 195 engineering students at two Midwestern universities were studied in relation to gender, class in school, major, ethnicity, native country, and native language. The overall learning strategy preference profile, which had not been previously measured for engineering students, was 33.3% Navigators, 39.5% Problem Solvers, and 27.2% Engagers. This profile was not statistically significantly different from the expected values for the general population. The profiles for chemical engineering majors, for students who were not born in the U.S.A., and for students whose native language was not English were statistically different from the general population. No relationships were found between learning strategy preferences and the demographic variables of gender or ethnicity. Because engineering students appear to be approximately equally divided among the three learning strategy preferences, a variety of instructional techniques addressing all three styles are recommended for use by instructors to meet students' preferences.

Introduction

Calls continue to be made 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 called for more research into engineering education. This includes 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." The U.S. National Academy of Engineering identified 14 grand challenges in engineering.[4] One of these was 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.

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*[5,6]) 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).[7] These styles are relatively stable and concern cognitive, affective and psychological behaviors about how learners perceive, interact with, and respond to a learning environment.[8] 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.[9] In that study, Kolb's Learning Style Inventory (LSI)[10] consisting of four learning styles (convergent, divergent, assimilation, and accommodation)[11] 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.[12] 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.[13] In another study that also used Kolb's LSI, engineering students at Morgan State University were predominantly assimilators.[14] Larkin-Hein and Budny gave specific instructional design recommendations for each type of learning style for engineering students.[15] However, Holvikivi argued that despite its popularity, the use of learning styles testing in engineering education is poorly understood.[16] 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.[17]

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."[18] Learning styles are believed to be stable and deeply ingrained processes for processing information.[19,20] 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.[21-23] Learning strategy preference is a potentially important learner variable[24] that could be used by instructors to enhance students' learning experiences.[17] 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 (see Appendix). An important advantage of this instrument is that it is simple to administer and currently the generally accepted method for measuring learning strategy preferences.[17] Three distinct learning strategy groups were identified: Navigators, Problem Solvers, and Engagers.[25] *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 was established as relatively evenly distributed: 36.5% Navigators, 31.7% Problem Solvers, and 31.8% Engagers (Conti, 2009).[25]

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.[26] 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.[27] To date there have not been any studies to determine the ATLAS-defined learning strategy preferences of engineers, the occupational group of interest here.

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

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.[28] 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 using the ATLAS instrument. 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 31% and males 69% of the total sample. The sample from University B had twice as high a percentage of females as University A. Most (67%) of the respondents were 20 years old or younger. The age distribution between the two universities was comparable. Note that one subject did not provide their age. There was approximately the same number of subjects from each school.

Table 1 Distribution of sample by gender and age (N = 195).

	University A		University B		Total	
	n	%	*n*	%	*n*	%
Gender						
Female	20	21%	40	40%	60	30.8%
Male	76	79%	59	60%	135	69.2%
Total	96	49%	99	51%	195	100%
Age Range						
17-18	32	33%	30	30%	62	31.8%
19-20	33	34%	35	35%	68	34.9%
21-22	23	24%	23	23%	46	23.6%
23+	8	8%	10	10%	18	9.2%
Missing	0	0%	1	1%	1	0.5%
Total	96	49%	99	51%	195	100%

Table 2 shows the school information (class and major) for the respondents. The highest proportion of the subjects was Freshman and the lowest Graduate Student. Note that University A does not have a graduate engineering program. The two most common majors represented in the sample were chemical and mechanical engineering students. Note that University A does not have chemical or petroleum engineering. In the Undecided/Other/Multiple category, for those that specified, two students reported as Unspecified. Two students did not report their major.

Table 2 Distribution of subjects by class and major (N = 195).

	University A		University B		Total	
	n	%	*N*	%	*n*	%
Class in School						
Freshman	40	42%	50	51%	90	46.2%
Sophomore	12	13%	19	19%	31	15.9%
Junior	28	29%	10	10%	38	19.5%
Senior	16	17%	13	13%	29	14.9%
Graduate student	0	0%	7	7%	7	3.6%
Total	96	49%	99	51%	195	100%
Major						
Biomedical Engineering	9	9%	2	2%	11	5.6%
Chemical Engineering	0	0%	70	71%	70	35.9%
Electrical Engineering / Engineering with Electrical Concentration	11	11%	2	2%	13	6.7%
Engineering with Computer Concentration	10	10%	0	0%	10	5.1%
Engineering Physics	12	13%	1	1%	13	6.7%
Mechanical Engineering / Engineering with Mechanical Concentration	48	50%	6	6%	54	27.7%
Petroleum Engineering	0	0%	13	13%	13	6.7%
Undecided/Other/Multiple	6	6%	3	3%	9	4.6%
Missing	0	0%	2	2%	2	1.0%
Total	96	50%	99	50%	195	100%

Table 3 gives some cultural information about the respondents including ethnicity, native country, and native language. Most were Caucasian/White with Asians and Other/Multiple the next most reported. The distributions varied between the universities. In the Other/Multiple category, of those that specified, students reported African (2), Indian (2), Middle Eastern (14), and Native American (4). One student did not report their ethnicity. Nearly three quarters of the students were born in the U.S.A., although the percentages for each school varied somewhat. In the Other category, of those that specified, students reported native countries of Brazil (1), Burma (1), Cameroon (1), Canada (3), China (8), Columbia (1), India (5), Kazakhstan (1), Malaysia (2), Mexico (2), Nigeria (2), Norway (1), Oman (2), Pakistan (1), Russia (1), Saudi Arabia (10), South Korea (2), Taiwan (2), Thailand (1), Venezuela (1), Vietnam (1), and Zimbabwe (1). For over three quarters of the students, English was their primary language, although the distribution between schools varied significantly. In the Other language category, of those that specified, students reported Arabic (13), Chinese (3), Hindi (1), Kazakh (1), Korean (2), Malayalam (1), Mandarin (2), Norwegian (1), Portuguese (1), Spanish (4), Tamil (1), Telugu (1), Thai (1), Urdu (2), Vietnamese (1), and Zo-Burmese (1). One student did not provide their primary language.

Table 3 Respondents' cultural attributes (ethnicity, native country, and native language) (N = 195).

	University A		University B		Total	
	n	%	*n*	%	*n*	%
Ethnicity						
African American	9	9%	1	1%	10	5.1%
Asian	4	4%	27	27%	31	15.9%
Caucasian/White	62	65%	52	53%	114	58.5%
Hispanic/Latino	9	9%	2	2%	11	5.6%
Other/Multiple	11	12%	17	17%	28	14.4%
Missing	1	1%	0	0%	1	0.5%
Total	96	49%	99	51%	195	100%
Native Country						
U.S.A.	83	86%	62	63%	145	74.4%
Other	13	14%	37	37%	50	25.6%
Total	96	49%	99	51%	195	100%
Native Language						
English	88	92%	64	65%	152	77.9%
Other	7	7%	35	35%	42	21.5%
Missing	1	1%	0	0%	1	0.5%
Total	96	49%	99	51%	195	100%

Results and Discussion

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.[25] Birzer and Nolan specifically sampled police officers from a particular police force.[26] The percentages of 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 engineering students who were Engagers was about the same as for the law enforcement sample, both of which were lower than the General Population 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 quite present a statistically significant difference at the 95% confidence level for learning strategy preferences ($\chi^2 = 5.443$, $df = 2$, $p = 0.066$).

Table 4 Learning strategy preference by subject type (N = 195).

Learning Strategy Preference	General Population (Conti, 2009)		Law Enforcement (Birzer and Nolan, 2002)		Engineering Students (this study)	
	n	%	*n*	%	*n*	%
Navigator	1121	36.5%	19	23.8%	65	33.3%
Problem Solver	973	31.7%	40	50.0%	77	39.5%
Engager	976	31.8%	21	26.3%	53	27.2%
Total	3070	100%	80	100%	195	100%

Table 5 shows a comparison of the distribution of learning strategy preferences by institution. A Pearson chi-square analysis of these data ($\chi^2 = 2.673$, $df = 2$, $p = 0.263$) did not present a statistically significant difference for learning strategy preferences between the two institutions.

Table 5 Learning strategy preference by institution (N = 195).

Gender	Navigator		Problem Solver		Engager		Total
	n	%	*n*	%	*n*	%	
University A	31	32.3%	34	35.4%	31	32.3%	96
University B	34	34.3%	43	43.4%	22	22.2%	99
Total	65	33.3%	77	39.5%	53	27.2%	195

Table 6 shows learning strategy preference by gender for this study. There was no statistically significant difference ($\chi^2 = 3.478$, $df = 2$, $p = 0.173$) in the distribution of learning strategy preferences between females and males.

Table 6 Learning strategy preference by gender (N = 195).

Gender	Navigator		Problem Solver		Engager		Total
	n	%	*n*	%	*n*	%	
Female	25	42%	23	38%	12	20%	60
Male	40	30%	54	40%	41	30%	135
Total	65	33.3%	77	39.5%	53	27.2%	195

Table 7 compares the distribution of learning strategy preference for chemical, mechanical, and all engineering students (there were not enough of the other majors for individual comparisons). Chemical engineering majors had a profile that was statistically significantly different from the general population ($\chi^2 = 7.608$, $df = 2$, $p = 0.022$), with concentrations in Navigator and Problem Solving preferences and fewer than expected Engagers.

Table 7 Learning strategy preference by major (N = 195).

Major	Navigator		Problem Solver		Engager		Total
	n	%	*n*	%	*n*	%	*n*
Chemical Engineering	28	40.0%	30	42.9%	12	17.1%	70
Mechanical Engineering	17	31.5%	19	35.2%	18	33.3%	54
All Engineering	65	33.3%	77	39.5%	53	27.2%	195

Table 8 shows a comparison of learning strategy distributions by ethnicity. No statistically significant difference ($\chi^2 = 10.333$, $df = 10$, $p = 0.412$) was found overall for ethnicity, which was heavily weighted toward Caucasian/Whites. There was almost a statistically significant difference ($\chi^2 = 5.927$, $df = 2$, $p = 0.052$) between the Asian engineering students and the general population. The Asian students were predominantly Problem Solvers. There were not enough African Americans or Hispanic/Latinos for a valid statistical analysis. However, the small samples of each showed a preponderance of Problem Solvers among the African Americans and a preponderance of Engagers among the Hispanic/Latinos, both of which warrant further investigation in future research studies.

Table 8 Learning strategy preference by ethnicity (N = 195).

	Navigator		Problem Solver		Engager		Total	
	n	%	*n*	%	*n*	%	*n*	%
Ethnicity								
African American	2	20%	5	50%	3	30%	10	5.1%
Asian	9	29%	16	52%	6	19%	31	15.9%
Caucasian/White	41	36%	40	35%	33	29%	114	58.5%
Hispanic/Latino	3	27%	2	18%	6	55%	11	5.6%
Other	8	33%	11	46%	5	21%	24	12.3%
Multiple	2	50%	2	50%	0	0%	4	2.1%
Missing	0	0%	1	100%	0	0%	1	0.5%
Total	65	33.3%	77	39.5%	53	27.2%	195	100%

Table 9 shows a comparison of learning strategy distributions by native country and native language. No statistically significant difference ($\chi^2 = 5.292$, $df = 2$, $p = 0.071$) was found for those born in the U.S.A. However, there was a statistically significant difference for those who were not born in the U.S.A. compared to the general population ($\chi^2 = 9.535$, $df = 2$, $p = 0.009$). For this group, there was a preponderance of Problem Solvers. There was no statistically significant difference ($\chi^2 = 3.050$, $df = 2$, $p = 0.218$) as a function of native language. There was a statistically significant difference ($\chi^2 = 6.980$, $df = 2$, $p = 0.031$) between those engineering students whose native language was not English and the general population.

Table 9 Learning strategy preference by native country and native language (N = 195).

	Navigator		Problem Solver		Engager		Total
	n	%	*n*	%	*n*	%	*n*
Native Country							
U.S.A.	54	37%	51	35%	40	28%	145
Other	11	22%	26	52%	13	26%	50
Total	65	33.3%	77	39.5%	53	27.2%	195
Native Language							
English	52	34%	55	36%	45	30%	152
Other	13	31%	21	50%	8	19%	42
Missing	0	0%	1	100%	0	0%	1
Total	65	33.3%	77	39.5%	53	27.2%	195

Conclusions and Recommendations

The overall learning strategy preference profile for engineering students was not statistically significantly different from the established general population norms for ATLAS. The most common learning strategy preference for the engineering students in this study was Problem Solver. Sheppard et al. (2009) wrote, “Engineering practice is, in its essence, problem solving.”[29] Conti reported that no statistically significant differences were found to be associated with any demographic variables such as gender or race.[25] Similarly for this study, no relationship was found between learning strategy preferences and gender. However, there was a statistically significant difference in learning strategy preferences for those students who were not born in the U.S.A. and for those whose native language was not English, compared to the established norms for ATLAS. Also, the profile for chemical engineering majors was statistically different from the general population. Further study of the learning strategy preferences of Asian, African American, and Hispanic/Latino engineering students is warranted as their profiles may differ from 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. Felder and Silverman (1988) recommended that teachers use techniques to address a range of learning styles for engineering students to enhance learning.[7] Rutz and Westheider (2006) recommended that teachers use a variety of instructional methods to engage all learners.[12] This study suggests similarly that a range of techniques should be used as the engineering students were comparably divided among the three learning strategy preferences. General instructor recommendations for each learning strategy preference are given in the Appendix. Instructors must be careful not to disproportionately design instructional materials and methods for their own learning strategy preference and instead should use a variety of techniques to address the preferences of all students.

Instructors may want to administer ATLAS at the beginning of a course, both to find out the learning strategy profile of those enrolled in a particular class and so the students themselves will find out their own preference and understand the other preferences. It may also 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 engineering 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 adult learning strategies concept and the ATLAS instrument, it may be possible to improve instructional practice in engineering education and to better prepare engineers to engage effectively with their colleagues in the workplace.

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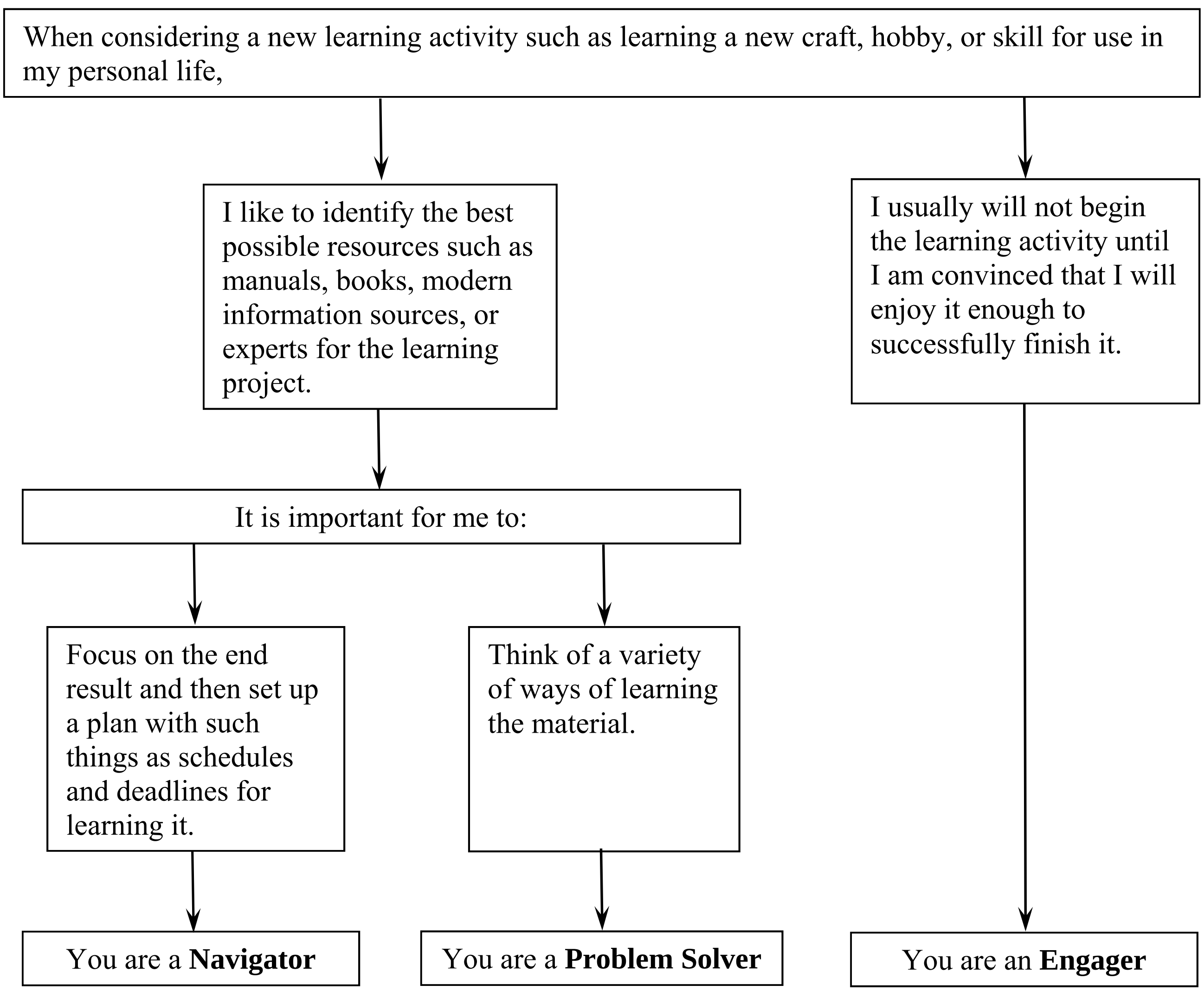
Appendix – ATLAS Instrument

ATLAS

(***A***ssessing ***T***he ***L***earning Strategies of ***A***dult***S***

Directions: The following statements are related to learning in real-life situations in which you control the learning situation. These are situations that are **not** in a formal school. For each one, select the response that best fits you, and follow the arrows to find the group to which you belong.



Groups of Learners

Navigators

Description: Focused learners who chart a course for learning and follow it.

Characteristics: Focus on the learning process that is external to them by relying heavily on planning and monitoring the learning task, on identifying resources, and on the critical use of resources.

Instructor: Schedules and deadlines helpful. Outlining objectives and expectations, summarizing main points, giving prompt feedback, and preparing instructional situation for subsequent lessons.

Problem Solvers

Description: Learners who rely heavily on all the strategies in the area of critical thinking.

Characteristics: Test assumptions, generate alternatives, practice conditional acceptance, as well as adjusting their learning process, use many external aids, and identify many resources. Like to use human resources and usually do not do well on multiple-choice tests.

Instructor: Provide an environment of practical experimentation, give examples from personal experience, and assess learning with open-ended questions and problem-solving activities.

Engagers

Description: Passionate learners who love to learn, learn with feeling, and learn best when actively engaged in a meaningful manner.

Characteristics: Must have an internal sense of the importance of the learning to them personally before getting involved in the learning. Once confident of the value of the learning, likes to maintain a focus on the material to be learned. Operates out of the Affective Domain related to learning.

Instructor: Provide an atmosphere that creates a relationship between the learner, the task, and the teacher. Focus on learning rather than evaluation and encouraging personal exploration for learning. Group work also helps to create a positive environment.

Bibliographical Information

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