Cognitive Style and Learning Preferences in Engineering Undergraduates

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Abstract

This paper describes a preliminary investigation of the relationships between cognitive style and learning preferences among undergraduate engineering students. Cognitive style is defined as the strategic, stable, characteristic, preferred manner in which people respond to and seek to bring about change, including the solution of problems. It is a dimension of personality that does not change over time. Learning preferences refer to the different ways our students access, process, and express information within the classroom setting. In this research, correlations between these fundamental concepts are explored to help us better understand our students and their learning needs. In addition to a full report of the research findings thus far, this paper also includes a brief summary of relevant cognitive style theory, a detailed description of the assessment instruments and methodology used, and lessons learned for future research.

1.0 Introduction

While cognitive issues have always existed in engineering education, the scholarly application of psychological principles by engineering educators themselves is relatively recent. This joint study between the University of Wisconsin-Platteville and Pennsylvania State University-Great Valley was initiated in Summer/Fall 2001 to support the on-going interest in the integration of cognitive style research into the engineering classroom. In particular, the cognitive styles of 44 undergraduate students enrolled in an Introduction to Environmental Engineering course were assessed using the Kirton Adaption-Innovation (KAI) Inventory[3,6]. The students' cognitive styles were then correlated to various learning preferences using the results of survey questions and an evaluation of their effectiveness at writing-to-learn exercises. Although this research is exploratory and still in its early stages, the results suggest some interesting conclusions for engineering educators.

In Section 2.0, an overview of the course under study is given, as well as some general issues that led us to pursue this research. Section 3.0 presents a brief review of Adaption-Innovation Theory (the cognitive style framework used in this study), the Kirton Adaption-Innovation (KAI) Inventory (the corresponding assessment instrument), and details concerning its administration. Section 4.0 discusses learning preferences and the definitions we applied in this research, as well as a description of the data collection and general methodology. Section 5.0 presents our research findings thus far, including the reported KAI scores and both qualitative and quantitative analyses of the relationships between cognitive style and learning preferences as we have defined them. Finally, Section 6.0 addresses our conclusions, lessons learned from this project, and plans for future work in this area.

2.0 Course Overview and Problem Identification

We assessed the cognitive style and learning preferences of students enrolled in Introduction to Environmental Engineering (CE334) at UW-Platteville. This course is required of all Civil and Environmental Engineering students, and contains three 1-hour lectures and one 2-hour laboratory period per week. Dr. Parker taught the two laboratory sections during the period of this study. The course contained 44 juniors and seniors, and included students who enrolled at their first opportunity and students who put it off until their final semester.

Engineering students at UW-P who have made it through the challenging calculus, physics, and chemistry requirements (such as those enrolled in CE334) appear in general to be more adaptive than innovative. This “gut feeling” was the impetus for this study, and was based on observations such as students’ reluctance to tackle problems that are not completely defined or carefully constrained by the professor. Moreover, we feel that a heterogeneous group (with respect to cognitive style) of engineers will be more effective at designing solutions in a team setting in the long term. Exploring this perceived skew toward the adaptive end of the cognitive style continuum using the KAI was a primary motivator for the study.

Assessing the cognitive style of students also presented an opportunity to determine if various learning preferences (such as the perceived reluctance of students to engage in open-ended problems) could be correlated to cognitive style. Thus, we assessed a variety of learning preferences, which are discussed further in Section 4.0.

3.0 Cognitive Style: Theory and Application

Fundamentals of Adaption-Innovation Theory

This study is based on the cognitive style theory of Dr. Michael J. Kirton, an eminent British organizational psychologist. This theory is well established and has been highly validated in practice for over 25 years, with hundreds of international journal articles and graduate theses devoted to its study and application, particularly in the field of Management. While the KAI inventory is generally less familiar to engineers, it has been favorably compared to the Gregorc Style Delineator[2] and shown to have very small correlations with some elements of the Myers-Briggs Type Indicator[6]. Only a brief summary of this theory will be presented here, but interested readers may find further details in Kirton’s major works[3,4,6].

Kirton's Adaption-Innovation Theory is based on the assumption that all people solve problems and are creative, since both are the results of the same brain function. The theory distinguishes carefully between *level* and *style* of problem solving and creativity, or more simply, between cognitive level and cognitive style. *Cognitive level* refers to an individual's inherent potential capacity (such as intelligence) or manifest capacity (such as learned competence). *Cognitive style*, on the other hand, is defined as the "strategic, stable, characteristic, preferred manner in which people respond to and seek to bring about change" (including the solution of problems)[6], and it is these preferences with which Adaption-Innovation theory is concerned. Cognitive level must be assessed by other means.

Cognitive style differences, as measured by the Kirton Adaption-Innovation Inventory (or KAI), lie on a continuum and range from strong adaption to strong innovation (see Figure 1). For large general populations, the distribution of scores forms a normal curve. Smaller groups can be predictably different from general populations, depending on their problem-solving orientation, and may exhibit skewed distributions about different means.

One key distinction to the differences between adaptive and innovative individuals may be described as follows: Individuals who are more adaptive prefer to operate with more structure, and with more of this structure consensually agreed, than do more innovative individuals. More innovative individuals prefer solving problems with less structure, and they are less concerned with consensus concerning the structure's design or even existence[3,4]. Please note the use of the terms "more adaptive" and "more innovative" in this paper. These terms are more precise for describing such a continuous range of styles, and they are preferable to the terms "adaptors" and "innovators," which incorrectly imply two separate "boxed" types.

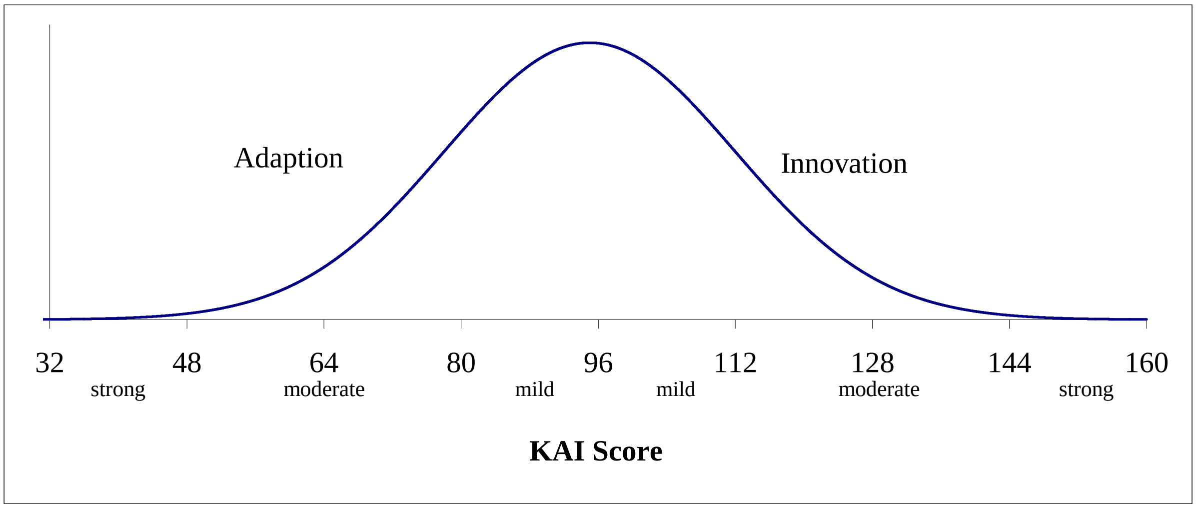

Figure 1: The Adaption-Innovation Continuum

In general, more adaptive individuals approach problems from within the given frame of reference (or paradigm) and strive to produce solutions that are "better" rather than "different". They are especially good at fine-tuning the current rules and procedures in order to make them

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operate as effectively as possible. The more innovative, on the other hand, tend to detach a given problem from its customary frame of reference and search for solutions that are typically seen as "different," although they may or may not be "better". One way of summarizing this basic difference is to say that the more adaptive prefer to solve problems *using* the rules, while the more innovative tend to solve (the same) problems *despite* the rules[5].

These differences in cognitive style produce distinctive patterns of behavior, which are particularly important when groups of individuals come together to solve problems collaboratively. More adaptive problem solvers generally accept problems as they have been defined, along with any agreed-upon constraints. In collecting data, they tend to be exhaustive and favor information and perspectives that are closely related to the original problem structure. When generating ideas, more adaptive individuals prefer to generate a few novel and creative solutions which are relevant, readily acceptable, and aimed at improvements on the current paradigm. These solutions are often relatively easier to implement than solutions generated by a more innovative person. When evaluating and implementing solutions, the more adaptive problem solver looks for a quick resolution to the problem which will limit disruption and immediately increase efficiency[1,4,5].

More innovative problem solvers, on the other hand, tend to reject the original, generally accepted definition of a problem and redefine it. This new view of the problem may be difficult to communicate to others, but it may also bring new clarity. In collecting data, the more innovative tend to look outside the original problem structure for different perspectives, which they bring into the solution process. When generating ideas, more innovative individuals generally produce numerous novel and creative ideas, some of which are not acceptable to others or may not appear relevant to the problem. When evaluating and implementing solutions, the more innovative problem solver is less concerned with immediate efficiency and potential disruption, and tends to look ahead to potential long-term gains[1,4,5].

The KAI Inventory

M. J. Kirton introduced the Kirton Adaption-Innovation Inventory[3], or KAI, in 1976. The inventory measures preferred thinking, or cognitive, style. Respondents answer 33 questions that focus on how easy or difficult it is for a person to present himself or herself consistently, over a long period of time, in particular ways. Each answer is assigned a value using a 5-point scale. The inventory is easy to understand and can typically be completed in less than 15 minutes. The KAI is one of the most highly validated psychological instruments in existence today. Supporting evidence for this claim may be found in the KAI Manual[6], which details the results of extensive testing and research studies using the instrument.

As shown in Figure 1, a person's overall KAI score will fall between 32 and 160, with a score of 32 representing the theoretical limit of highest adaption, and a score of 160 representing the theoretical limit of highest innovation. In practice, scores typically fall between 40 and 150. For large general populations, the distribution of scores forms a normal curve with a theoretical mean of 96. In the United States, the observed mean for the general population is 95, while the observed mean for U.S. engineers is 97. Males' scores are generally normally distributed around a mean of 98 and females' scores around a mean of 91. Additional statistics for these and other populations may also be found in the KAI Manual[6].

It is important to note once again that there is no correlation between KAI scores and any level measure. Thus, in this context, high scores are not "good" and low scores are not "bad"; it is the relative difference between the scores of two individuals or between an individual and the mean of a group that is important. In general, a difference of 10 points between individuals is noticeable over time. A difference of 20 points or more can lead to difficulties in communication and may require considerable *coping behavior*. Further discussion of coping behavior and its implications may be found in several of Kirton's works[3,4,6].

<u>Administration of the Instrument</u>

A qualified facilitator who has received the appropriate certification and training must administer and score the KAI inventories. This certification process is tightly controlled to preserve the integrity of the instrument and prevent its misuse. Self-scorable and on-line versions are not available. Dr. Jablokow has received advanced training and certification in the instrument and was the sole administrator of the KAI in this study. The KAI inventories were distributed to the students at the beginning of the semester. Basic confidential feedback of the students' scores was provided several weeks later. No student's score was revealed to any other individual (student, faculty or otherwise) during this study, in keeping with the ethical standards of the instrument.

4.0 Learning Preferences: Theory and Application

For this study, *learning preferences* are defined as the specific methods individuals prefer to use to access, process, and express information. Learning preferences include study habits, techniques for learning (e.g. rote memorization, write-to-learn), the types of problems people prefer to solve, social aspects (e.g. group setting or solo), and environmental aspects (e.g. preferred characteristics of study area). A survey and in-class writing assignments were employed to investigate a variety of learning preferences in this study. These instruments, the targeted learning preference(s), and the analysis of their results are discussed below.

<u>Survey</u>

A survey was constructed and administered to the class on October 29. Students were asked to perform the survey on their own time, and hand in their responses by November 5. Thirty-nine surveys were returned. A copy of the survey is provided in Appendix A. Due to the short lead time available prior to this study, the survey was not formally validated.

The authors intended the survey to provide some preliminary information on the following learning preferences: class format, type of laboratory activities, tendencies to explore additional topics independently, and the types of problems to solve. The analysis of survey results consisted primarily of scatter plots and tabulated results of the students' responses as a function of their KAI scores. A summary of these results is presented and discussed in Section 5.0. All tabular results are provided in Appendix B.

In-Class Writing Exercises

Two in-class writing exercises were employed to evaluate students' preference for "writing-to-learn" strategies. The premise of "writing-to-learn" is that writing is not so much a method of communication as it is a generative tool for problem solving and critical thought. The writing exercises employed were "free writes," in which students were instructed to continuously write for five minutes. The free writes were assigned in class during weeks #2 and #14.

Two types of free writes were employed, and each was designed to investigate a different write-to-learn strategy. The objective of the first exercise was to see if students could use free writing to pinpoint what they didn't understand about a complex environmental engineering concept. Students were instructed to write about the most difficult concept in class. The second free write was carried out immediately before giving students a "create-a-lab" assignment. The create-a-lab assignment, to be carried out in teams, requires students to create and solve a laboratory assignment that can be used by future classes. The purpose of the second free write was to allow students to brainstorm ideas for the create-a-lab assignment.

To analyze the free writes, the essays were read without knowing the students' names or KAI scores. The reading was done after the completion of the semester, so students would feel more comfortable writing without any possible impact on their grades. Free writes in the first group were judged to be "effective" if the students were able to condense their thoughts and arrive at a clearer understanding of the chosen concept. For the second free write, the free writes were judged effective if the student was able to generate two or more ideas or to expand on a single idea. Also, any evidence of frustration was noted. For example, phrases such as "I really don't understand what we are supposed to be writing about" and "I really do not have any ideas on what to do for lack of ideas and lack of time to think of anything" were counted as evidence of frustration.

5.0 Research Findings and Observations

Reported KAI Scores

A summary of the students' KAI scores is presented in Table 1 below. A few simple observations concerning this group of students can be made from this data. First, as a whole, this group was slightly more adaptive than both the general U.S. population (mean of 95), and U.S. engineers in general (mean of 97)[6], although the difference was not large in either case. Still, a difference of only 5 points between the means of two groups is noticeable over time, so differences in the behavior of this small cohort compared to a large group of engineers might become significant after a prolonged period. The histogram shown in Figure 2 also confirms the slight adaptive skew of this group. The range for the group was fairly large (60 points) and included several moderately high innovative scores (e.g. 121, 135).

SAMPLE	SIZE (N)	RANGE	MEAN
All Students	43	75 - 135	92
Male students only	34	75 - 135	94
Female students only	9	75 - 95	84

Table 1: Student KAI Scores

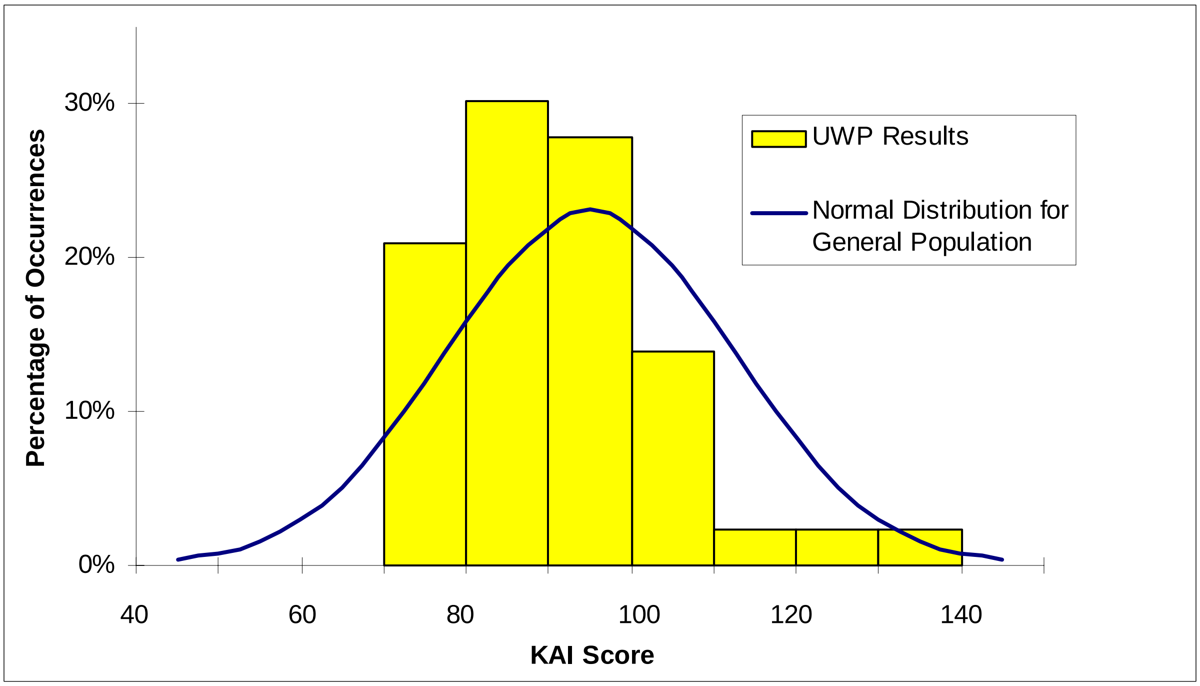

Figure 2: KAI Results

Second, there was an interesting difference in the score distributions of male and female students. The male students' scores were distributed around a noticeably higher mean (mean of 94) than the female students (mean of 84). This difference is mirrored in the general population, in which males' scores generally are distributed around a mean of 98 and females' scores around a mean of 91. Notice again the slight adaptive skew of these two gender-based subgroups as compared to the general population.

Survey Instrument

Several scatter plots were constructed from the data in which the student response to the questions was plotted against their KAI score. Four plots that support KAI theory are presented in this section; Appendix B contains the data for all survey questions in tabular format. Note that in the scatter plots, a vertical red dashed line is included to show the mean of the KAI scores of students involved in this study (92). Therefore, symbols to the right of this line correspond to the more innovative students, while symbols to the left of the line correspond to the more adaptive students, relative to this mean.

The reply to Question #2 is presented in Figure 3. While most of the group (77%) indicated a preference for structured experiments, independent of cognitive style, it is interesting to note that all of the students with a preference for open-ended experiments (8%) were among the more innovative. This supports KAI theory, which predicts a positive correlation between innovativeness and higher levels of tolerance for ambiguity (i.e. less structure).

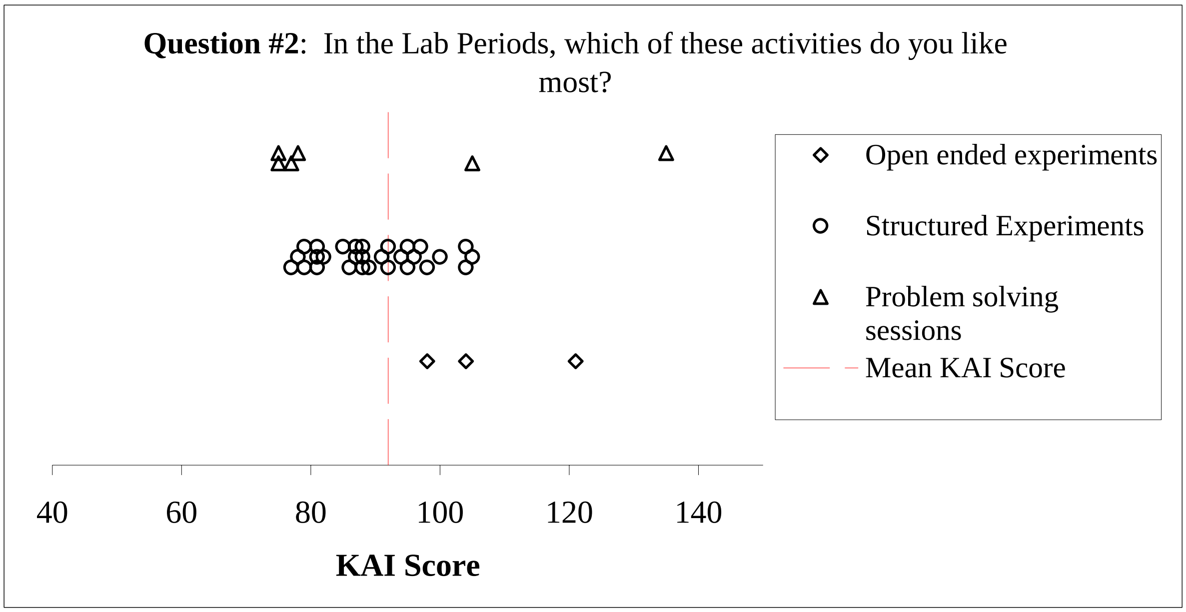

Figure 3: Analysis of Survey Question #2

In Question #5 of the survey, students were asked how they preferred to solve problems. Their choices were either to "a) generate a lot of ideas before choosing a solution" or "b) choose a solution quickly and move on to implementation." KAI theory predicts that more innovative people enjoy generating numerous ideas regardless of their practicality, while the more adaptive aim at producing an acceptable and relevant solution. Survey answers, shown in Figure 4, reveal that a majority of the more adaptive students (67%) indicated a preference for choosing solutions and implementation, while 72% of the more innovative students indicated a preference for idea generation.

Student responses to Question #6 suggest that the preference for problem type also seems to correlate with differences in cognitive style. Note that a majority of the more adaptive students (71%) indicated a preference for problems with one correct answer, while a majority of the more innovative students (59%) preferred problems with several possible answers. These results are illustrated in Figure 5.

The responses to Question #8 showed that among the more adaptive students, a majority (71%) indicated a preference for applications, while the more innovative students registered a slight preference for fundamentals (56%). This is indicative of the more adaptive person's preference for refining a system in a practical way, whereas a more innovative person may be interested in a broader perspective. Student responses to this question are shown in Figure 6.

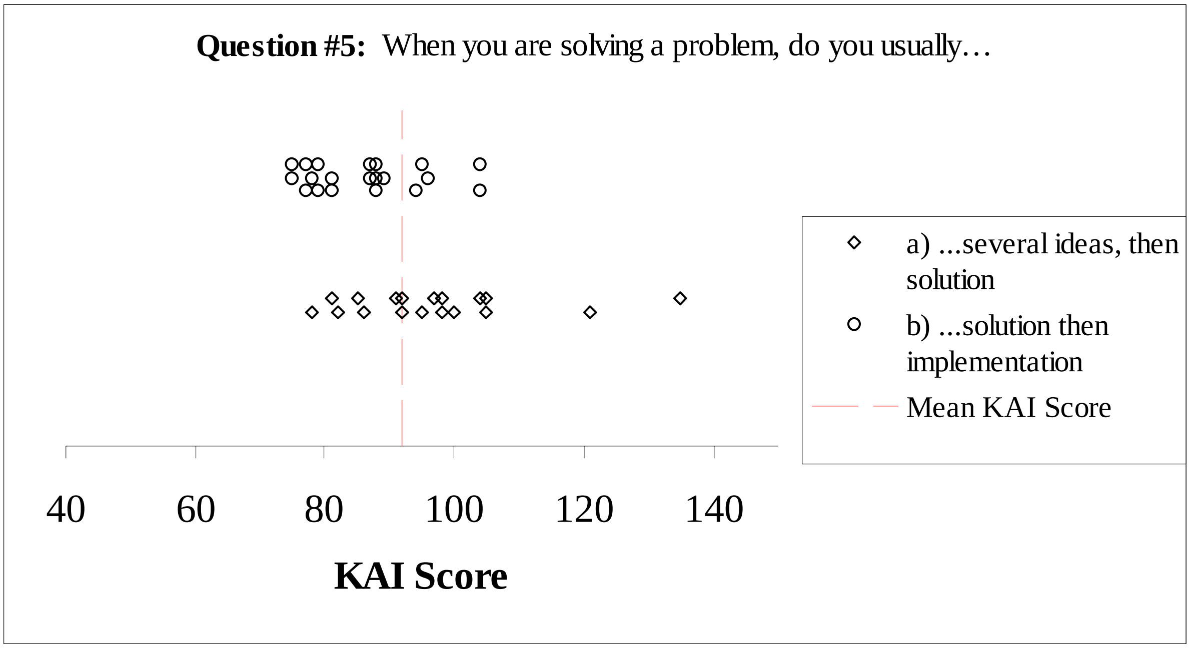

Figure 4: Analysis of Survey Question #5

Some interesting observations were also gained from the more qualitative questions in the survey, which concerned teamwork likes and dislikes, as well as self-assessed personal contributions (see Appendix A: Questions 9, 10, and 11). Consistent with KAI theory, the results suggest that the more adaptive students are more concerned with issues of internal group cohesiveness and structure, including coordination of time and resources, inclusion of team members, building consensus, and dependence on others. As one more adaptive student commented: "I try to include everyone, so when I don't get a response, it's difficult to deal with." These same students identified their two most valuable contributions to the team as organization and making decisions.

The more innovative students, on the other hand, are less concerned with issues of structure and cohesion, but may tend to "enjoy" the experience more. For example, one of the most innovative students commented: "I have not worked all that much with my team. All I can say is that I like them." The results also suggest that these students see themselves as "idea people," rather than organizers. On a general and positive note, both the more adaptive and more innovative students seemed to recognize the value of other students' ideas in the problem solving process.

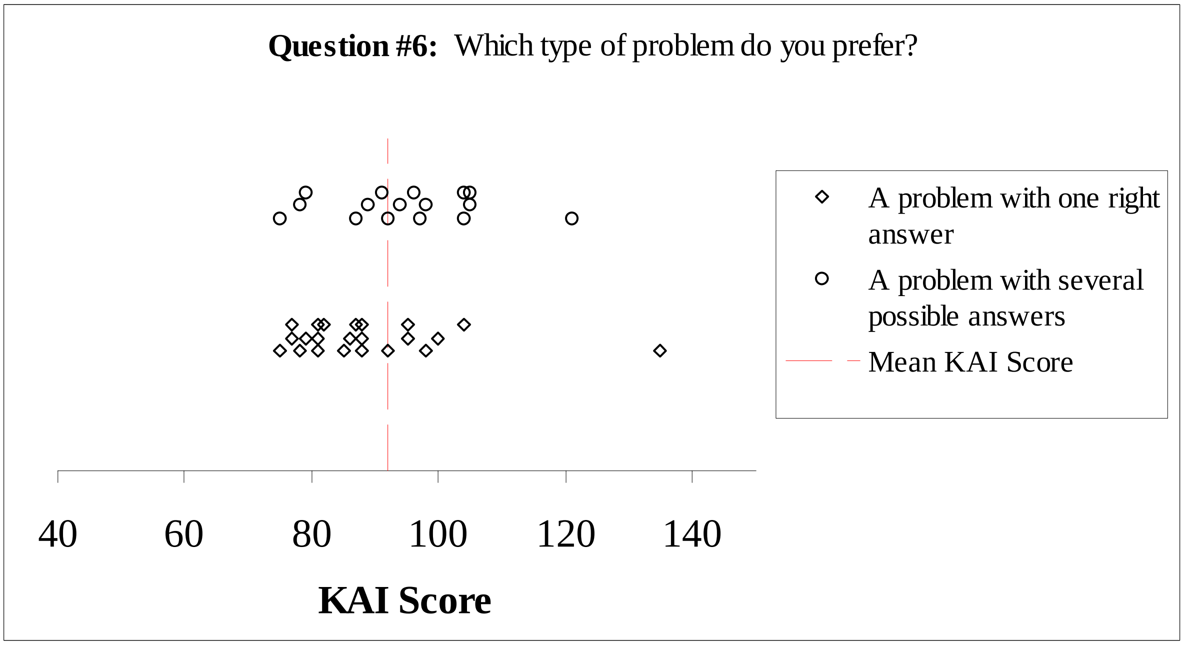

Figure 5: Analysis of Survey Question #6

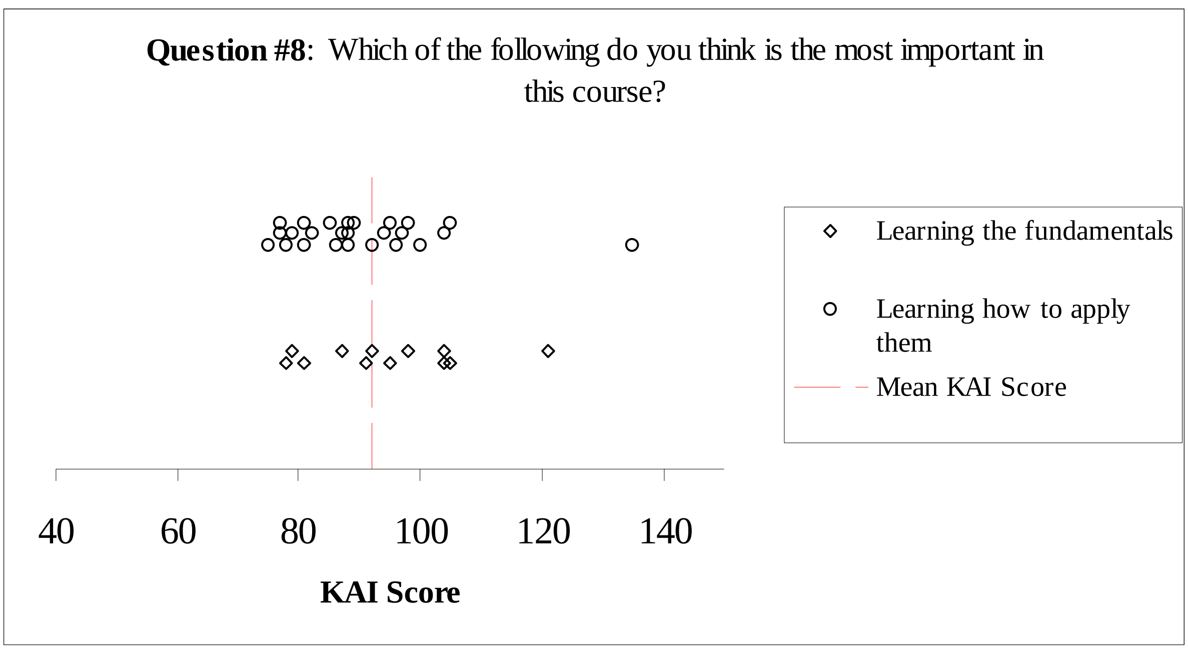

Figure 6: Analysis of Survey Question #8

Writing to Learn Results

Analysis of the first free write showed that none of the students were able to successfully get to the root of their difficulties with a complex concept. One possible reason is that the time allotted for students to write was too brief (5 minutes).

An analysis of the second free write, in which students brainstormed ideas for their create-a-lab, did not reveal any correlation between the effectiveness of the exercise and the KAI scores of the students. However, some of the student comments were extremely revealing and consistent with KAI theory. For example, one of the most adaptive students wrote "I'm not too creative when it comes to this stuff, because I like to follow directions, not make up my own like in this experiment thing." Unfortunately, this view – i.e. that adaptive individuals are not creative – is common among adaptive and innovative people alike. KAI theory is clear in refuting this belief. All people are creative, at different levels and with different styles.

Perhaps the most interesting result from this analysis was the assessment of whether any frustration was evidenced in the free writes. Only seven students seemed to be frustrated, and this frustration was either directed toward the open-ended nature of the create-a-lab or the difficulty in writing to generate ideas. As shown in Figure 7, of the seven students who appeared to be frustrated, six of these were the more adaptive students. This is also consistent with KAI theory regarding both idea generation and preference for structure.

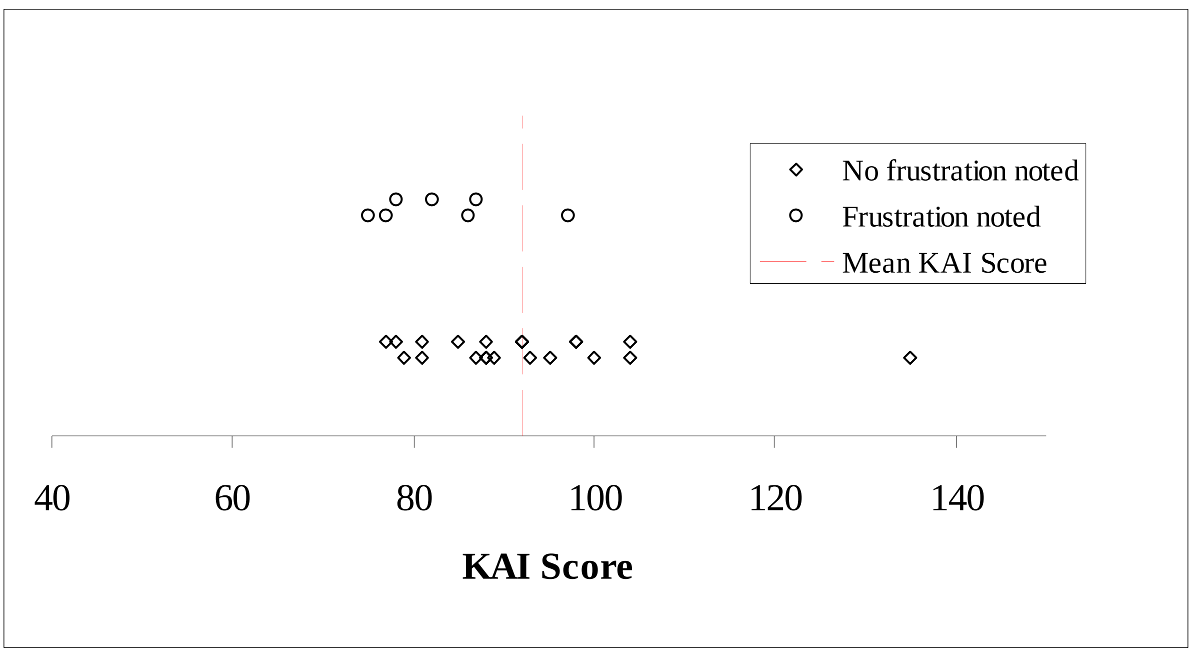

Figure 7: Assessment of Student Frustration in Free Write Exercise

5.0 Conclusions and Plans for Future Work

Results from this administration of the KAI instrument supported our conjecture that the cognitive styles of students enrolled in CE334 may be slightly skewed towards the adaptive end of the KAI continuum. Determining whether this is a long-term trend will require further investigation with repeated administrations of the KAI over several years. If consistent over time, this skew is relevant to the engineering educator through predictable relationships between cognitive style and classroom behaviors. For example, the more adaptively oriented the class, the more frustration they are likely to experience with open-ended assignments and writing-to-learn exercises. A more innovatively oriented class, on the other hand, is more likely to be more comfortable with these activities.

The responses to several survey questions appeared to be consistent with KAI theory, and *suggest* the following:

a) More innovative students have a higher tolerance for ambiguity;
b) More adaptive students prefer choosing a solution quickly and moving on to implementation, rather than generating many ideas before implementation; the opposite tendency may be seen in the more innovative students;
c) More adaptive students prefer to define a system in a practical way through applications, rather than focus on the broader perspective.

These preliminary data will help us formulate new hypotheses that can be tested and subjected to more rigorous statistical evaluation. For example, we would like to extend our exploration of problem solving approaches and problem types to investigate the interplay between cognitive styles in a team setting. We would also like to explore a characterization of the design process relative to cognitive style differences. Finally, at the time of this writing, the authors have been made aware of Kolb's Learning Style Inventory[7,8] as an alternative for assessing learning styles in the future.

We learned (or confirmed) several valuable lessons from this preliminary research that will be useful in the future. First, the logistics of remote research projects must be carefully planned and coordinated to ensure the best results. Second, the design and use of surveys is an area in which we need further training and possibly outside assistance. And finally, we were reminded that the study of human behavior is a complex undertaking, with engineers being no exception. Even so, we believe such study to be both important and necessary, if we are to continue to improve the quality of engineering education in the future.

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Biographical Information

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Appendix A: Student Survey

Name ______________________________

KAI Study: Student Questionnaire #1

1. In this course, which learning format do you like best:

    a. Lectures
    b. Labs

2. In the lab periods, which of these activities do you like *most*:

    a. Open ended experiments
    b. Structured experiments
    c. Problem solving sessions

3. Which do you like *least*?

    a. Open ended experiments
    b. Structured experiments
    c. Problem solving sessions

4. When you are doing an experiment, do you ever think about investigating things that are not explicitly part of the assignment? Yes or No

    a. If Yes, how often do you actually carry out your additional investigations? (i) always (ii) often (iii) sometimes (iv) rarely (v) never

5. When you are solving a problem, do you usually prefer to:

    a. Generate a lot of ideas before choosing a solution
    b. Choose a solution quickly and move on to implementation

6. Which type of problem do you prefer?

    a. A problem with one right answer
    b. A problem with several possible answers

PLEASE CONTINUE ON BACK

7. If you could choose, which of the following would you like to have in this course?

    a. More details about topics
    b. Broader range of topics

8. Which of the following do you think is most important in this course:

    a. Learning the fundamentals
    b. Learning how to apply them

9. What do you like *most* about working with your team?

10. What do you like *least* about working with your team?

11. What are *your* most valuable contributions to your team? (e.g. organization, lots of ideas, decision making)

Appendix B: Tabulated Survey Results

FORMAT	≤ MEAN [N=21]	>MEAN [N=18]	TOTALS
Lectures	15	9	24
Labs	6	9	15

Q1: Preferred Learning Format

ACTIVITY	≤ MEAN [N=21]	>MEAN [N=18]	TOTALS
Open-ended experiments	0	3	3
Structured experiments	17	13	30
Problem solving sessions	4	2	6

Q2: Preferred Lab Activities

ACTIVITY	≤ MEAN [N=21]	>MEAN [N=18]	TOTALS
Open-ended experiments	16	11	27
Structured experiments	0	3	3
Problem solving sessions	5	4	9

Q3: Least Liked Lab Activities

EXPAND	≤ MEAN [N=21]	>MEAN [N=18]	TOTALS
Yes	12	11	23
No	9	7	16

Q4: Tendency to Expand on Assignment

APPROACH	≤ MEAN [N=21]	>MEAN [N=18]	TOTALS
Generate ideas	7	13	20
Choose solution	14	5	19

Q5: Preference for Problem Solving Approach

PROBLEM TYPE	≤ MEAN [N=21]	>MEAN [N=18]	TOTALS
One answer	15	7	22
Several answers	6	10	16

Q6: Preference for Problem Type

CONTENT	≤ MEAN [N=21]	>MEAN [N=18]	TOTALS
More details	9	11	20
Broader range	7	9	16

Q7: Preference for Depth versus Breadth

CONTENT	≤ MEAN [N=21]	>MEAN [N=18]	TOTALS
Fundamentals	6	10	16
Application	15	8	23

Q8: Preference for Fundamentals versus Application

FACTOR	≤ MEAN [N=21]	>MEAN [N=18]	TOTALS
Different/more ideas	13	8	21
Working together	9	6	15
Less work per person	3	4	7
Fun	1	4	5

Q9: Like Most About Teamwork

FACTOR	≤ MEAN [N=21]	>MEAN [N=18]	TOTALS
Coordination (time, resources)	8	4	12
Unfair work load	6	6	12
Lack of consensus	7	2	9
Dependence on others	5	1	6
Lack of organization or efficiency	1	2	3
Nothing	1	2	3

Q10: Like Least About Teamwork

CONTRIBUTION	≤ MEAN [N=21]	>MEAN [N=18]	TOTALS
Organization	13	7	20
Ideas	6	10	16
Decision Making	8	6	14
Participation	5	2	7
Writing Skills	4	1	5

Q11: Personal Contributions