Thinking About Thinking: Problem Solving Style in the Engineering Classroom

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Abstract

This paper will discuss a powerful tool called the Kirton Adaption-Innovation Inventory, or KAI, which can be used to help describe a student's problem solving style[4,6]. Developed by psychologist M. J. Kirton, the KAI provides valuable feedback which helps students understand the types of problems with which they are naturally more comfortable, as well as those which will challenge them the most. Armed with this information, students are able to determine which new skills they will need to enhance their engineering problem solving ability. In addition to helping students with their individual development, knowledge of the KAI is also helpful in forming productive teams, both in the classroom and in the field. The KAI is being used regularly in engineering problem solving and design courses at the Pennsylvania State University. Specific examples of its use and application in these classrooms will be discussed.

1.0 Introduction

Problem solving lies at the heart of the engineering profession. Engineering instruction is based largely, if not entirely, on teaching students how to solve problems of many different types and levels of complexity. Yet the problem solving styles of the students themselves are rarely considered in the learning process. An individual's problem solving style refers to his or her approach to problems, including the manner in which he or she deals with the various stages of problem definition, data gathering, idea generation, evaluation of solutions, and final solution implementation.

In general, a mismatch of any kind between problem and problem solver can lead to inefficiency and frustration. Typically, difficulties with problem solving are attributed to a lack of knowledge or ability, but based on the theory and applications presented here, we find that an individual's problem solving style also influences the level of his or her success with certain problems. The objective of this discussion is to present an existing cognitive theory which helps provide insight into another dimension of the problem solving process. We begin with a brief description of the basic tenets of M. J. Kirton's Adaption-Innovation Theory[6].

2.0 Fundamentals of Adaption-Innovation Theory

Kirton's Adaption-Innovation (AI) Theory is based on two assumptions: first, that all people are creative, and second, that all people solve problems[7]. Individuals differ, however, in the cognitive style in which they do so. Kirton makes a sharp distinction between *level* and *style* of problem solving/creativity, which is critical to an understanding of the theory. Cognitive *level* refers to a person's potential capacity, such as intelligence, or to learned ability, such as design competency. Cognitive *style*, on the other hand, refers to the manner in which cognitive tasks are accomplished, and it is this dimension of cognitive function which Adaption-Innovation Theory addresses exclusively[7].

It is important to note here that Kirton's definition of the word *innovation* is independent of and may differ from common usage. In AI Theory, innovation refers specifically to one *style* of creativity or problem solving, while more popular usage often implies that innovation means the same thing as something 'new', 'creative', or even 'better'. Extreme care must be taken not to confuse style with level; there is no correlation between problem solving style as measured by the KAI and any measure of cognitive level (such as intelligence quotient)[8]. In general, the creativity which all people possess can be measured in two independent ways. We can measure creative *level* by asking the question '*How creative* are you?', and we can measure creative *style* by asking '*How* are you *creative*?'. Adaption-Innovation Theory provides us with an explicit way to answer this second question.

In AI Theory, the differences in cognitive style lie along a normally distributed continuum, which ranges from strong adaption on one end to strong innovation on the other[6,7], as shown below in Figure 1. The fundamental distinction between the styles can be described in terms of an individual's preferred approach to solving problems. More adaptive problem solvers, for example, prefer problems which are associated with more structure, and they are especially mindful when this structure has been determined and agreed upon with the consensus of others. More innovative problem solvers, on the other hand, prefer solving problems with less structure, and they are less concerned maintaining a consensus[5].

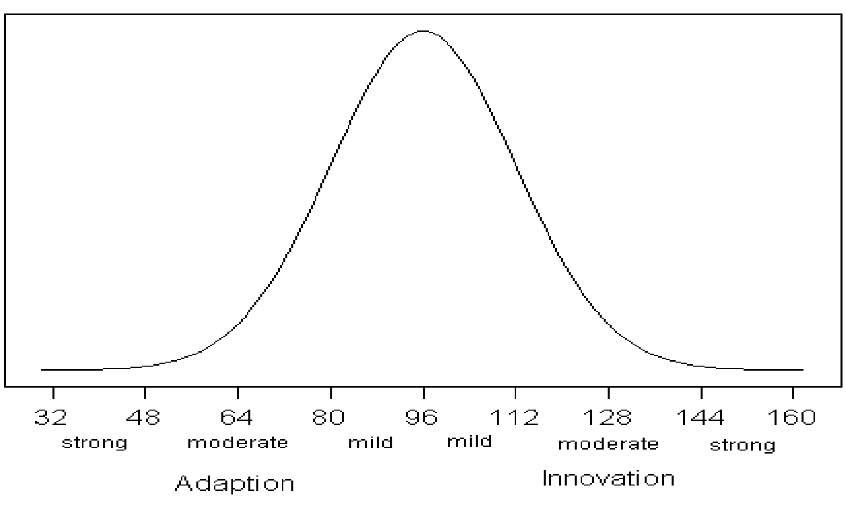

Figure 1: The Adaption-Innovation Continuum

Problem solving is commonly considered to include the following stages: problem definition, the collection of data, idea generation, evaluation of solutions, and final solution implementation[9]. 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 which 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 doing things "better". 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[5,7].

The advantages of the adaptive problem solving approach are clear. Adaptors are, in general, best at incorporating new information or solutions into existing structures and systems, which, in turn, makes them very efficient[7]. Such individuals are essential for maintaining the foundations of a given system. In times of crisis, however, they may experience great difficulty and discomfort if they are required to make any changes in their established role or routine. In other words, adaptors help preserve an existing system, but they may hold onto an obsolete system too long.

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 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. Their ideas and solutions are often aimed at doing things "differently". 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[5,7].

The advantages of the more innovative approach to problem solving are equally clear. Innovators use new problems as opportunities to build new systems or restructure the old, making them greater risk-takers. They are essential in times of crisis or great change, but they are often frustrated by the duties required to maintain a system's foundations. In other words, innovators help create new systems, but they may discard an existing system too soon.

Note the intentional use throughout this discussion of the phrases "more adaptive" and "more innovative" when describing and comparing individual problem solvers. This helps reinforce the nature of cognitive style as a continuous range and helps prevent the separation of people into rigid categories which is both imprecise and potentially destructive. Similar to the relative descriptors "large" and "small", it is more accurate and useful to say that one individual is more or less adaptive (or innovative) than another. For example, it is possible for the same individual to be more adaptive than his coworkers, more innovative than his children, and less innovative than his friends. While the terms "adaptor" and "innovator" may be used occasionally for simplicity, it is imperative to use them carefully to avoid labeling people in a pejorative way.

Further discussion of adaptive and innovative strategies in the various stages of problem solving will follow in Section 4.

3.0 The Kirton Adaption-Innovation Inventory

Organizational psychologist M. J. Kirton introduced the Kirton Adaption-Innovation Inventory[4], or KAI, in 1976. The inventory measures preferred thinking, or problem solving, style. Respondents answer 33 questions which focus on how easy or difficult it is for a person to present himself 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 20 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[8], which details the results of extensive testing and research studies using the instrument. A qualified facilitator who has received the appropriate certification and training must score the KAI forms. This certification process is tightly controlled to preserve the integrity of the instrument and prevent its misuse. Self-scorable forms are not available.

Specifically, 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 (see Figure 1). 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. Additional statistics for these and other populations can be found in the KAI Manual[8].

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 which is important. For example, a person with a score of 75 is simultaneously more adaptive than a person with a score of 110 *and* more innovative than a person with a score of 50. In general, a difference of 10 points between people is noticeable over time. A difference of 20 points or more can lead to difficulties in communication and may require considerable *coping behavior*[7]. Further discussion of coping behavior may be found in several of Kirton's publications[6,8].

In addition to the overall score, three subscores may be obtained which give further insight into a person's preferred problem solving and thinking style. These scores are Sufficiency of Originality (SO), Efficiency (E), and Rule/Group Conformity (R)[4,7]. The SO subscore helps explain the different preferences people have for dealing with original ideas. In general, a more adaptive person tends to produce a few novel ideas at a time which are recognized quite readily as sound, relevant, and easy to implement. Such adaptive solutions often lead to improvements in the current design or system. A more innovative person, on the other hand, prefers to produce a proliferation of ideas, some of which are relevant and immediately applicable and some of which are not. These latter ideas may be seen as "crazy" or "out of the box", depending on the perspective, and if adopted, may lead to major changes in the current system or design.

In terms of efficiency (indicated by the E subscore), adaptors are more likely to work efficiently within the given system or structure. They tend to be more orderly and methodical as they work with data and solutions. Innovators, on the other hand, are often considered to be inefficient and unpredictable in the way they operate, because of their tendency to go outside the given system for new ideas and perspectives. This is, however, the most efficient way to produce something "different", which is the innovator's aim.

Rule/Group Conformity (indicated by the R subscore) refers to a person's preference for working within or disregarding formal rules and informal (personal) structures when solving problems. The more innovative problem solver, since he or she is less concerned with consensus and tradition, is more likely to solve problems by bending, or even breaking, the rules. This can lead to dissension within a group, causing others to view the innovator as disruptive and abrasive. On the other hand, the more adaptive problem solver prefers to abide by the rules, using them as guidelines for his work. Adaptors will strive to maintain group cohesion and order, which is useful for helping a group work well together. However, their attachment to the rules may be interpreted as lagging behind in times of change.

4.0 Implications of Adaption-Innovation in the Problem Solving Process

Given the brief description of some typical characteristics of adaptive and innovative problem solvers above, it is easy to see how these qualities will influence the problem solving process in an engineering environment. Engineering students have different experiences when dealing with certain types of problems or stages in the problem solving process, depending on their own adaptive or innovative style. We will now consider each stage in the problem solving process in more detail and briefly discuss how a student's problem solving style might affect his or her performance and success.

Problem Definition

Problem formulation and definition is often considered to be the most important and one of the most challenging stages of problem solving. For a more adaptive student, the chief aim of this stage is to define the problem as explicitly as possible in a way which is acceptable to the instructor and/or other members of a team. If a problem definition is supplied at the outset, an adaptor will accept this definition, clarify any questions he or she has about details, and endeavor to move forward to a quick solution[5]. If any part of the problem is not well-defined, the adaptor may be frustrated by the ambiguity and have difficulty moving beyond this stage. For a more innovative student, the problem definition stage can be very enjoyable if he or she is given some freedom to explore different problem formulations. Innovators delight in defining and redefining problems using new perspectives, even when a problem statement is supplied[5]. This can lead to difficulties, however, if they have not learned to discipline themselves and converge on a definition in a reasonable time.

Conclusions: Adaptors are highly adept at pinning down the definition of a problem once it has been generally agreed upon; however, they tend to have greater difficulty dealing with ambiguity in a problem statement and must learn skills to tolerate it. Innovators enjoy defining problems using new perspectives and are generally not bothered by ambiguity; however, they may spend too long in this stage at the expense of the others and must learn skills to focus their efforts.

Data Collection

Once the problem has been defined, an adaptive student will begin to search systematically for the data needed to solve it. This search will tend to remain well within the bounds of the discipline in which the problem was defined[5]. For example, if the student is asked to model a particular mechanical system, he or she will probably restrict the search for information to mechanical engineering texts and examples. A more innovative student, on the other hand, when asked to model the same system, may well extend the search for examples into other fields, such as biology or medicine. Innovators are also likely to be less organized in their search for data, jumping from one discipline to the next as potential new sources of information appear.

Conclusions: Adaptors must learn skills to help them recognize relevant sources of data which lie outside the explicit field of the given problem. Innovators, on the other hand, must learn to search the problem field more methodically, so they will not miss relevant information which is near to hand.

Idea Generation

As mentioned above, adaptors and innovators use different strategies when generating ideas. The adaptive strategy is to produce a sufficient number of creative ideas which are all connected to the problem in ways which are readily recognized[5,6]. If asked, adaptors will produce more ideas, but they prefer to do so a few at a time. The innovative strategy, on the other hand, is to spontaneously produce many creative ideas, some of which appear to be adaptive in nature (e.g. practical, sound) and some of which are more innovative (e.g. high risk, breakthrough)[7]. Innovators often have a difficult time choosing which of their many ideas to pursue, but they tend to choose a more innovative idea if given the opportunity.

Conclusions: Adaptors may need to learn new skills for generating ideas which are “out of the box” when their more adaptive ideas do not solve the given problem. Innovators often require skills to help them focus their idea generation so they do not drift too far afield with their suggestions (unless, of course, that is what is required).

Solution Evaluation and Implementation

When evaluating and implementing solutions to problems, both adaptors and innovators will remain true to form. A more adaptive student will tend to choose solutions which lead to greater efficiency (doing things “better”), are relatively easier to implement, and which will cause the least disruption[7]. This can lead to difficulties when the problem requires great change or a dramatically new approach for its solution, as may be the case in engineering research. A more innovative student, on the other hand, is more likely to choose solutions which reframe the problem (doing things “differently”), break new ground, and/or involve higher risk. This can be an advantage in the areas of research and invention; however, such solutions are also more likely to fail and may cause unwanted disruption[7].

Conclusions: Adaptors need to learn skills which will help them tolerate lower short-term efficiency in exchange for greater long-term gains as they choose which solutions to implement.

If they are patient, their natural talents will soon be required to fine-tune any high-risk solutions adopted by their more innovative colleagues. Innovators need to learn how to recognize when a more adaptive solution is the best choice, as well as toleration for the minute detail sometimes required in engineering applications.

5.0 Specific Classroom Applications

The KAI is currently being used in several design and problem solving courses at Pennsylvania State University. Students are typically asked to complete the KAI in the first or second class meeting. Brief descriptions of the KAI inventory, its history, and its underlying theory are provided at that time. The inventories are scored by a certified practitioner, and the results are interpreted and checked for validity during the following week. A three-hour feedback session is presented to the class within two weeks, during which time each student receives his or her individual KAI results. As is true in the ethical use of all psychological instruments, these results are confidential and may not be revealed to any other person without permission from the student.

The feedback session includes an in-depth discussion of AI Theory and its application using the KAI Inventory. The students' KAI scores are only revealed at the end of the session. In the interim, the SO, E, and R subscores are described, using specific examples and anecdotes, and the students are asked to estimate their own subscores. Most students are able to estimate their scores within 15 points, which demonstrates a reasonably high level of self-awareness.

To help demonstrate the power of the KAI instrument, students are placed in homogeneous groups (all KAI scores within 10 points of each other) and asked to perform various cognitive tasks, including different forms of brainstorming and idea generation. The students are *not* told how the groups are formed. Students are asked to note the quantity, quality and variety of their results, as well as the interpersonal dynamics which occur as they perform the task. In general, homogeneous groups work well together, and their ideas are understood and readily accepted by all members of the group[7]. Students note that working in these groups is very comfortable, and communication is generally easy.

Students are then placed in heterogeneous groups (KAI scores spread over a larger range with at least 10 points between individuals) and asked to perform the same cognitive tasks, also noting their results and the dynamics of the group. Again, the makeup of the group in terms of KAI scores is not revealed. In general, the heterogeneous groups experience more conflict and have greater difficulty accepting the ideas offered within the group. The more adaptive members of the heterogeneous groups describe the ideas of their more innovative partners as "crazy", "out in left field" and "not relevant". The more innovative members of the group, on the other hand, describe the ideas of their more adaptive partners as "boring", "obsolete" and "obvious". This particular exercise is excellent for demonstrating how we perceive the behavior of others as negative when it differs from our own preferences. Students note that, despite the conflict, working in these groups results in a wider variety of better ideas.

Following the activities of the two groups, students are asked to compare their experiences and hypothesize on possible explanations for any differences. This always leads to lively discussion and the relating of similar experiences in other courses. After this discussion, the assignment of homogeneous and heterogeneous groups is revealed, and the students are asked to consider any new insights they have gained. In addition to a better understanding of their own cognitive processes and the ability to identify skills which they need to learn, students report that this activity also helps them appreciate and work better with their peers. Many students express a desire to apply this knowledge in other courses when project teams are assigned.

Thus, the most powerful application of the KAI instrument in the classroom to date has been in the formation of productive teams for projects and other collaborative activities. In general, homogeneous teams from any area along the KAI continuum will work well together with little conflict and frustration. However, the types of problems they can solve effectively are limited. A highly adaptive team, for example, may excel at fine-tuning a current engineering design, but they may find it difficult to create a dramatically new design under tight time constraints. A highly innovative team, on the other hand, may easily and quickly produce multiple new concept designs, but they may find it a challenge to choose one design and bring it to implementation.

In contrast, heterogeneous teams generally experience more conflict and frustration, but the group's breadth of problem solving potential is much greater[7]. They are able to produce and implement detailed adaptive solutions, as well as unique innovative solutions. In the end, the more adaptive members of the team help keep the team on track, while the more innovative team members encourage the team to push the solution envelope. With an understanding of AI Theory and their own preferences in hand, students are able to summon the effort and tolerance necessary to overcome their cognitive style differences and perform effectively under these conditions. They note that, in the end, these teams are more productive and yield higher quality results than randomly chosen teams used in other courses.

6.0 Summary and Conclusions

This paper has presented, in brief, the basic principles of M. J. Kirton's Adaption-Innovation Theory[6,7], a description of the Kirton Adaption-Innovation Inventory (KAI)[4], and details of the application of this theory and instrument in engineering courses. In addition to a better understanding of personal cognitive style, the most valuable insights obtained thus far have been with respect to team formation and productivity. We can conclude that heterogeneous teams are most desirable due to their greater breadth in problem solving capacity, despite their greater potential for interpersonal conflict.

Extensive material relating to AI Theory and the KAI may be found in the literature, including applications in other fields, such as nursing[1], marketing[2], and management[3]. For details concerning certification and/or use of the KAI instrument in your own classroom, please contact this author.

Bibliography

1. Adams, C. E. Innovative Behavior in Nurse Executives. *Nursing Management*, 1993, Vol. 25, No. 5, pp. 44-50.

2. Foxall, G. R. Consumer Initiators: Adaptors and Innovators. *British Journal of Management*, 1994, Vol. 5, pp. S3-S12.

3. Foxall, G. R., and Hackett, P. M. W. Styles of Managerial Creativity: A Comparison of Adaption-Innovation in the United Kingdom, Australia and the United States. *British Journal of Management*, 1994, Vol. 5, pp. 85-100.

4. Kirton, M. J. Adaptors and Innovators: A Description and Measure. *Journal of Applied Psychology*, 1976, Vol. 61, No. 5, pp. 622-629.

5. Kirton, M. J. Adaptors and Innovators: The Way People Approach Problems. *Planned Innovation*, 1980, Vol. 3, pp. 51-54.

6. Kirton, M. J. A Theory of Cognitive Style. In *Adaptors and Innovators: Styles of Creativity and Problem Solving* (Ed.), 1994, Routledge, New York, pp. 1-33.

7. Kirton, M. J. *KAI Advanced Feedback Booklet*, 1998, Occupational Research Centre: Hertfordshire, UK.

8. Kirton, M. J. *Kirton Adaption-Innovation Inventory (KAI) Manual* (3rd Edition), 1998, Occupational Research Centre: Hertfordshire, UK.

9. Treffinger, D. J., Isaksen, S. C. and Dorval, K. B. Creative Problem Solving: An Overview. In *An Introduction to Creativity* (2nd Ed.), 1997, Copley Custom Publishing Group: Acton, MA, pp. 114-122.

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