Concept Maps in the Mechanical Engineering Curriculum

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In this paper concept maps, a pedagogical tool which improves the effectiveness of lectures and helps students achieve a higher level of understanding, will be discussed. Concept maps are a visual representation of ideas designed to illustrate the relationships between the ideas. There are a variety of ways concept maps can be used in the mechanical engineering curriculum. They can be used to help students understand the structure of the curriculum, the relationship between courses, and the material within a course. The reaction of students to the use of concept maps has been enthusiastically positive.

Introduction

The process for obtaining higher levels of learning is the same for any discipline[1]. The phases of a learning hierarchy are shown in Figure 1. A student must first learn the terminology and facts which make up the basic language of a discipline. After learning the facts and terminology the student is able to combine them to understand concepts. The more concepts a student possesses, the easier it is to form generalizations and to apply the concepts to a wide variety of problems. The lecture is one of the primary vehicles for information transmission in higher education today and is used by educators to help students in their journey through the learning hierarchy. However, for most students the basic lecture, when used exclusively, is not the most effective technique to facilitate optimum student learning and to help students understand complex and subtle interrelationships. For this reason, lectures must be supplemented with the textbook, homework, projects, group work, etc. Recently there has been a school of thought that emphasizes cooperative learning to the point of eliminating lectures completely. I believe that this is a mistake. Even though lectures have limitations, they remain an important tool to help professors facilitate student learning, especially if they can be made more effective. One method to improve the effectiveness of lectures is the use of visuals[1]. In this paper the visual pedagogical tool called the concept map will be discussed.

Concept maps are a visual aid to help students organize and understand groups of ideas or concepts. Creating an effective concept map requires experience and a depth of understanding that is typically beyond the level a student achieves by the end of a course, typically the “synthesis” or “appreciation” level in Bloom’s taxonomy of the cognitive domain[2]. For this reason it is important for professors to provide concept maps for the students. There are many different ways concept maps can be used. Although all of the examples of concept maps in this paper will be from the mechanical engineering curriculum, the ideas are equally applicable to other fields. The use of concept maps to help students understand the structure of the curriculum and the relationships between sequences of courses, and to help students understand and assimilate the material in a single course will be discussed.

Concept maps of a curriculum

A concept map of an entire mechanical engineering curriculum is shown in Figure 2. This map could be provided to the students in their freshman year. Often students do not understand the purpose of the courses in the freshman year and how they relate to and help advance their desire to be an engineer. They are also typically unfamiliar with the details of the curriculum of their desired major. By giving freshmen this concept map and explaining it to them it is hoped that motivation will be provided for the basic math and science courses taken by these students and it will reduce attrition since the students can see how the material in these courses fits into the entire curriculum and is critical for subsequent courses. The concept map shown in Fig. 2 is intended to provide a snapshot of the curriculum. Note that it does not show the individual courses or when courses are taken but rather the general areas of learning.

An example of how one of the blocks shown in Fig. 2, the mechanics block to be specific, can be expanded into a sequence of courses is shown in Figure 3. The prerequisites for each course are easily shown and the distribution of the courses throughout the four year curriculum is apparent. One way of viewing Figs. 2 and 3 is that Fig. 2 is presenting a global view of the subjects students are to learn in the curriculum and Fig. 3 presents the specific structure (i.e. sequence of courses) that has been designed to cover this material.

Concept maps within a course

In addition to illustrating the structure of an entire curriculum and helping students understand the relationships between sequences of courses, concept maps can be used within a single course to help students understand the purpose and goals for a course as well as to understand the specific technical content of a course. As an example of concept maps used in a specific course, several concept maps developed for a sophomore dynamics course will be presented. Figure 4 is a concept map to be used the first day of class to present the goals of the class. In this course, the goals can be grouped into three categories: 1) technical content to be mastered, 2) skills to be developed, and 3) experiences the students should have. It is useful for a professor to develop this type of concept map to help him or her evaluate the purpose of the course and to identify not only the technical content, but also the important skills and experiences the students should have by the completion of the course. This type of concept map does not present the details of how the goals for the course will be accomplished, but does provide the professor with criteria to evaluate in-class and out-of-class activities and to decide whether or not they will help achieve the course goals, and if they won't, then to redesign the activities. The content of Fig. 4 is really no different from what is usually contained in an administrative handout, but it is easier to understand and clearly indicates the three categories for the goals of the course.

Concept maps can also be used in several ways when covering the technical material of a course. The ultimate goal of a concept map used in a single course is to help students establish connections between the various topics covered in the course and to help the students organize concepts in their minds. From Fig. 4, it is seen that the technical content of dynamics can be grouped into the two broad categories of kinematics and kinetics. An example of a concept map in each of these two categories is discussed below. The first concept map to be discussed is an example of how concept maps can be used when presenting material in a single chapter and the second is an example of how concept maps can be used to relate the material presented in several chapters.

A concept map illustrating the relationship of topics typically covered in the area of particle kinematics is shown in Figure 5. A different concept map would be provided, or more likely produced by the students, for rigid body kinematics. When first seen, a concept map will frequently appear confusing and of little value. Concept maps become most useful to students when they are presented and discussed several times and each

element of the map is explained to the students. This is accomplished with Fig. 5 by projecting the concept map onto a corner of the classroom's front wall while covering the material in class. As a particular topic is discussed, its location in the concept map is shown to the students. This way, the concept map gradually acquires meaning as the material is covered and the links between topics are explained.

Another way to use concept maps is at the conclusion of several chapters to show how the topics from the different chapters are related. An example of this type of concept map is shown in Figure 6. The concept map shown in Fig. 6 was developed to help students identify what kinetics principles to apply when facing a new problem. The three basic kinetics principles discussed in dynamics, direct application of Newton's 2nd Law, work-energy methods, and impulse-momentum methods, are often presented in separate chapters in the textbook (Meriam's textbook is a notable exception[3]). When doing homework, students usually know what principle to apply based on what section in the book immediately precedes the assigned problem. On tests, the problems typically require a variety of different principles and students have difficulty knowing which ones to apply since they have never had to face a similar situation on the homework. The purpose of the concept map shown in Fig. 6 is to help students learn that the key to identifying what principle to apply when facing a new problem is found within the problem statement. This concept map also gives a brief procedure the students may follow when solving a problem once the required basic principles have been identified. This concept map was presented in class after all three kinetics concepts had been discussed and was used in conjunction with in-class group work. The students were assigned to groups and each group was given five problems for which they were required to identify the principle to apply when solving the problem. The students were not required to complete the solutions, but rather to simply map out a solution. In the last ten minutes of class, one student from each group was selected at random to explain how the group approached one of the problems (also selected at random).

As the course progresses and students become familiar with the structure and purpose behind concept maps it is useful to have students generate their own. These concept maps can be generated either individually or in groups. The process of creating their own concept maps forces students to attempt to evaluate and organize the material in a logical fashion and to begin to understand the material at the higher levels of understanding. By evaluating the students' concept maps, the professor can gain a better understanding of students' understanding of the material and can clear up any confusion the students may have.

Every time I have used concept maps within a course, the student feedback has been uniformly positive[4]. In fact, I have yet to receive a negative comment on concept maps. The primary difficulty in using concept maps is the time required to generate good ones. It has been my experience that they are continually being revised as I become more familiar with a course. Although I feel that concept maps are beneficial for all students, they can be especially helpful for visual learners.

Conclusions

There are a number of benefits to using concept maps for both the professor and the students. A concept map of an entire curriculum is useful to evaluate the entire curriculum and to see how all of the courses fit together into a unified and hopefully cohesive whole rather than a collection of unrelated courses. By drawing a concept map for a course, the professor is forced to evaluate the purpose of the course, how the material is related, and to identify the most important concepts in a course. Concept maps can be used in a single course to show the relationships between topics within a chapter and to show how the material in several chapters is related. Concept maps have proven to be an effective tool to improve the effectiveness of lectures and to help students achieve a greater depth of understanding of course material.

References

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3. Meriam, J. L., *Engineering Mechanics - Dynamics*, John Wiley and Sons, 1978.

4. Cornwell, P.J., "Teaching Dynamics using Modern Tools", Proceedings of the 1995 ASEE National Conference, Anaheim, CA, 1995.

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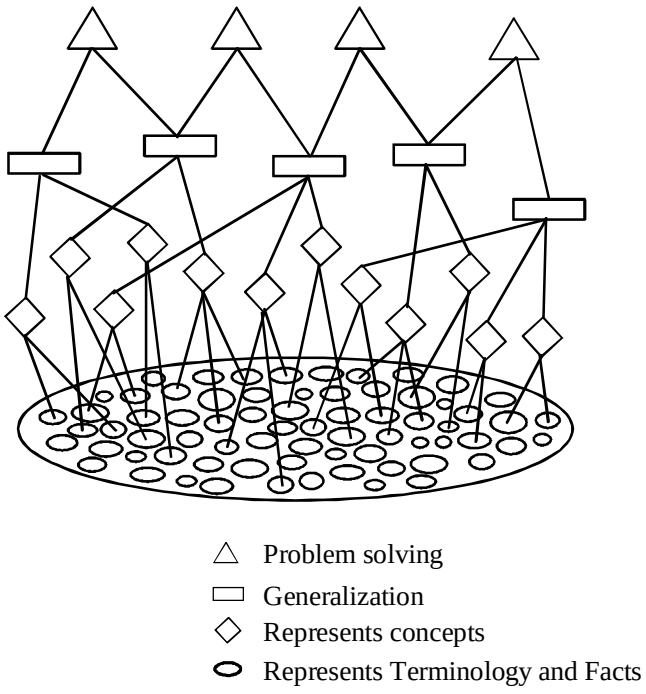

Figure 1 - Phases in a learning hierarchy[1].

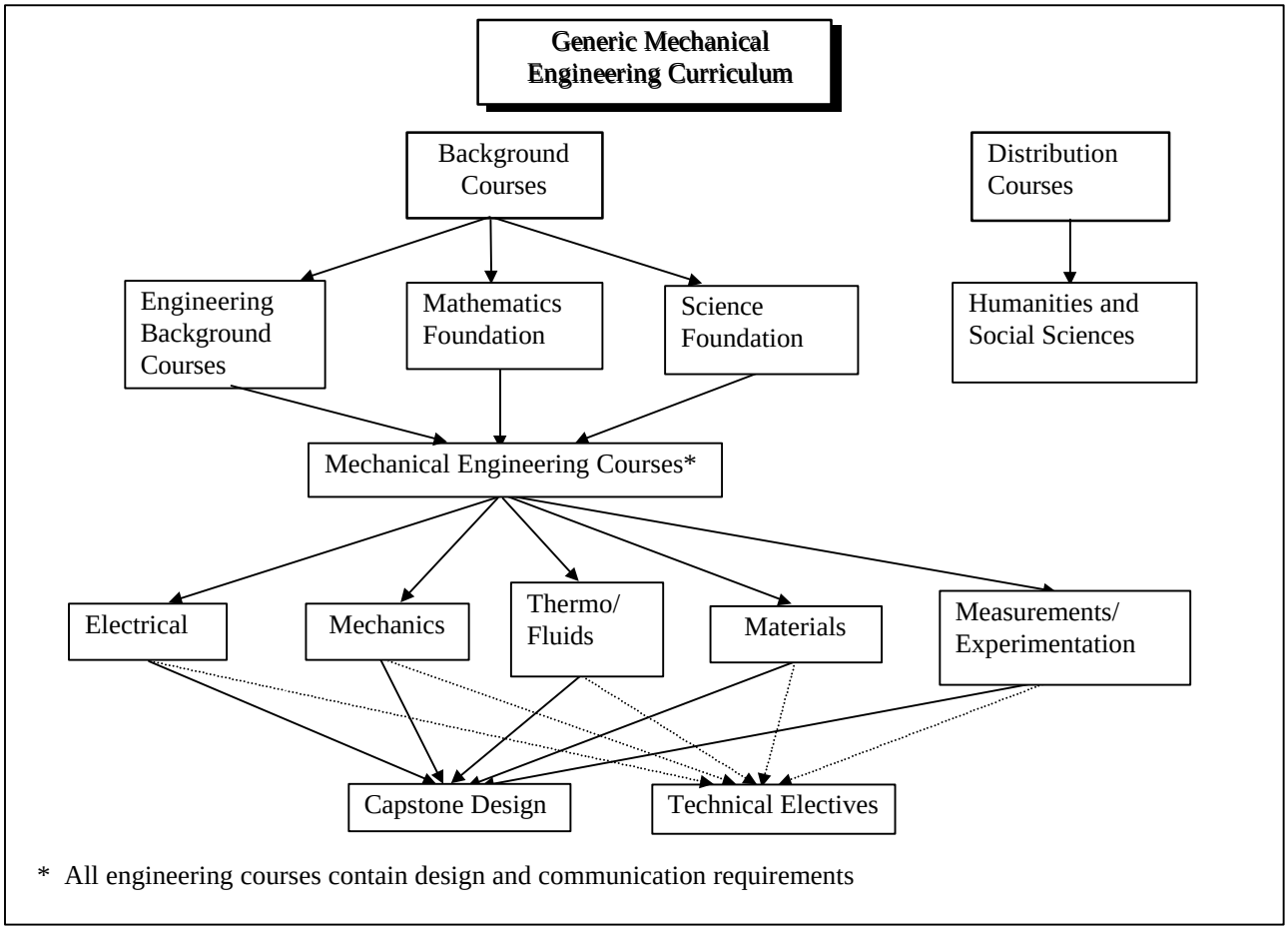

Figure 2 - Concept map for a mechanical engineering curriculum.

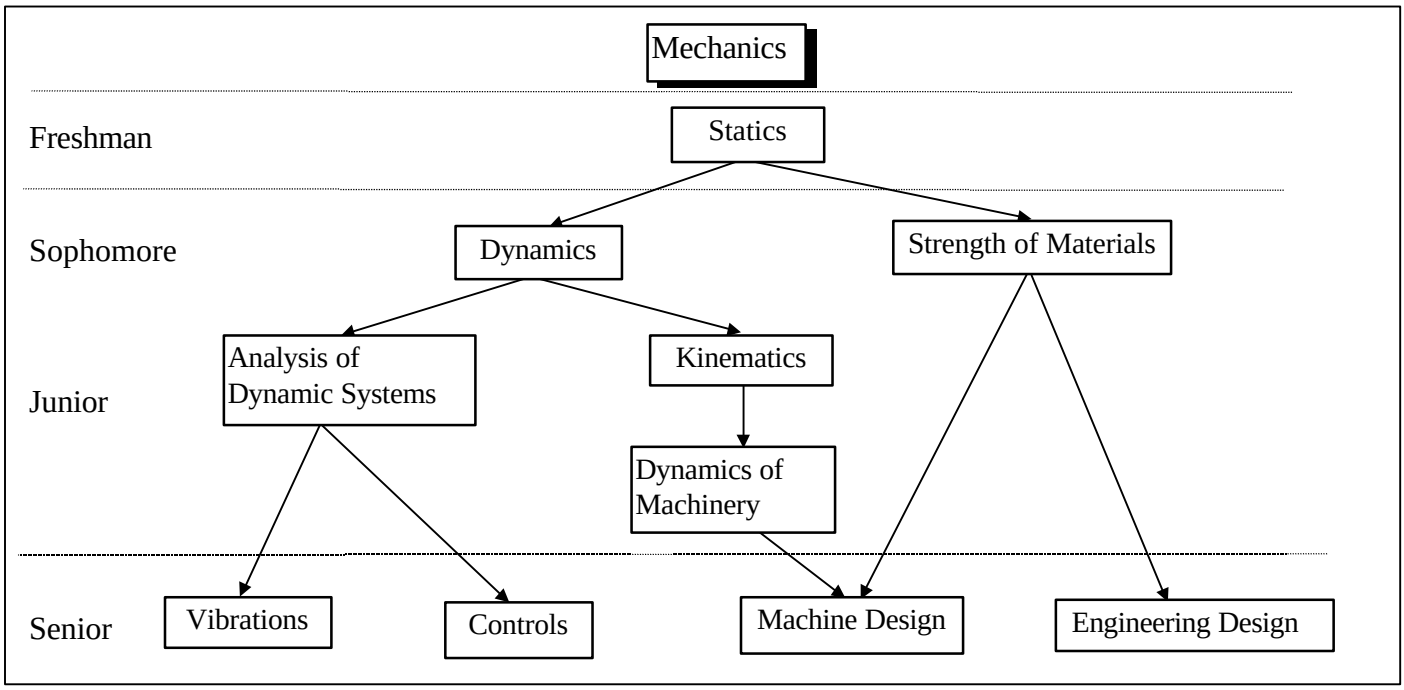

Figure 3 - Concept map showing the sequence of courses that focus on the mechanics portion of the curriculum.

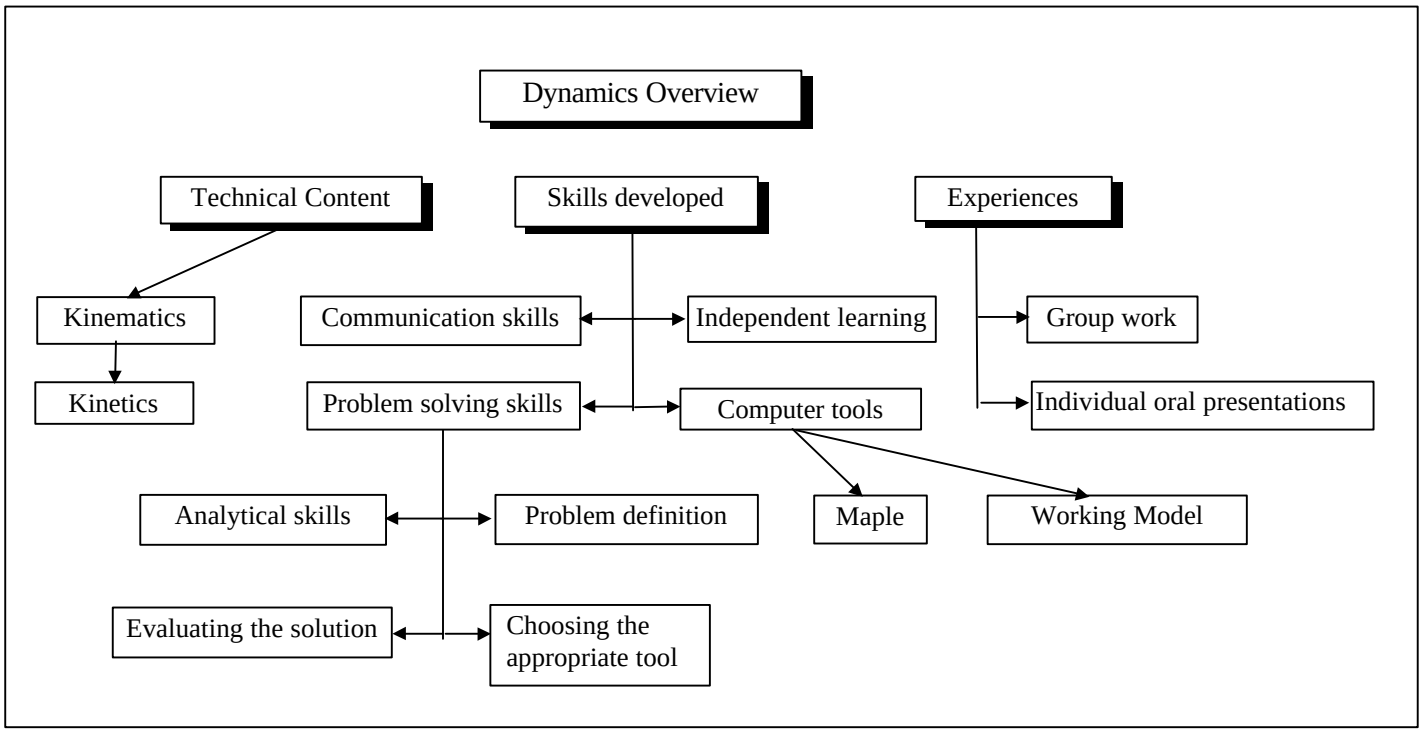

Figure 4 - Overview of goals for a dynamics course

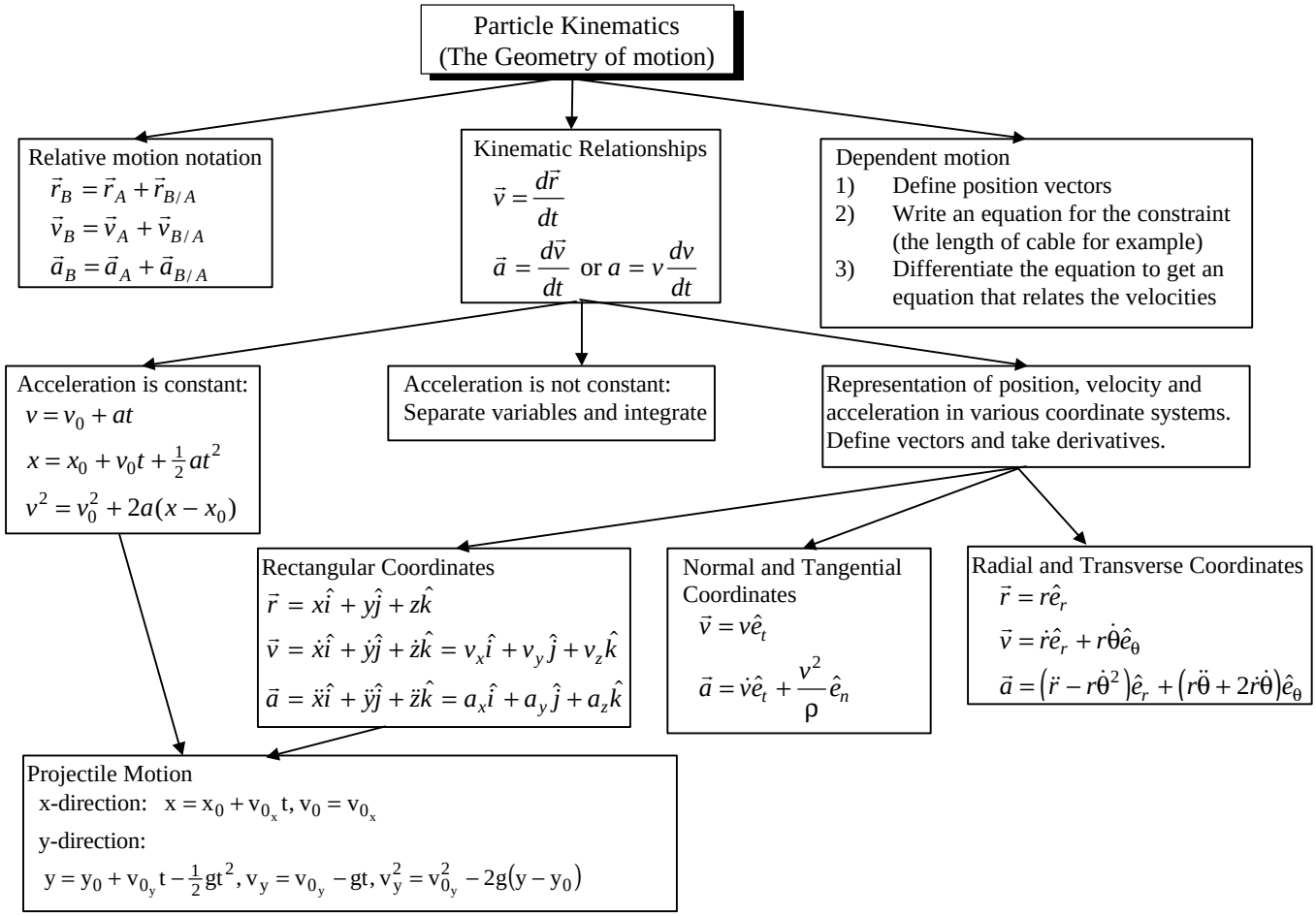

Figure 5 - Concept map for the topic of particle kinematics

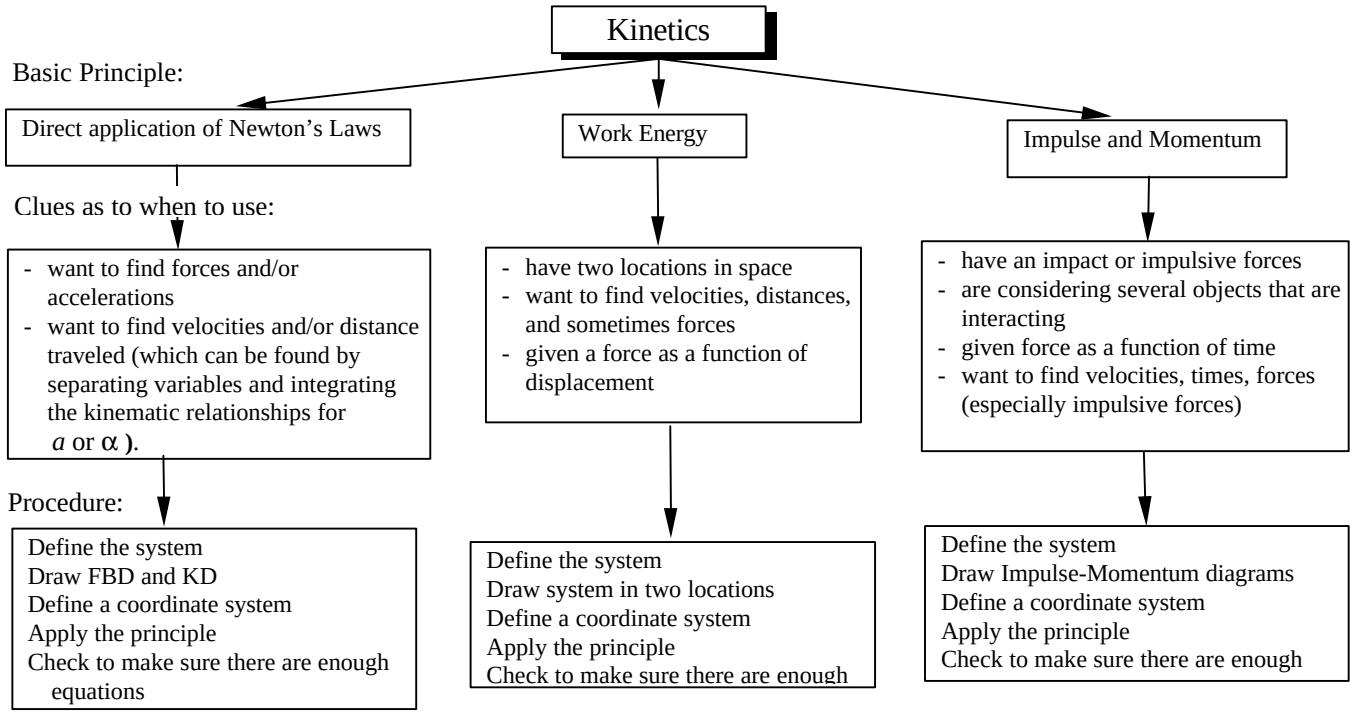

Figure 6 - Concept map for kinetics designed to help students identify the principles to apply when solving problems