Assessing understanding by means of venn diagrams

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Science Education

Assessing Understanding by Means of Venn Diagrams

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The recent past in science education research has seen a substantial growth in concern for the processes of science learning and for the nature and assessment of student understanding of concepts. These concerns have led to considerable discussion about methods of assessing the relations students perceive between concepts. Early work in this area used word association tests (e.g., Johnson, 1964, 1969; Preece, 1976; Shavelson, 1972; Shavelson & Stanton, 1975; Thro, 1978). Subsequent development of the word association task has also given information about the propositional links between concepts that are held by students (Gunstone, 1980a). More recently, concept maps or concept arrangement tasks have been employed (e.g., Champagne, Klopfer, DeSena, & Squires, 1981; Novak, 1981; Stewart, Van Kirk & Rowell, 1979). We discuss in this paper another form of task that can be used to reveal how students perceive relations between concepts. The task involves drawing Venn diagrams for classes of specified objects or events.

Venn diagrams, first developed by the English logician John Venn (1834–1923), have become common tools in propositional logic and related branches of mathematics such as Boolean algebra. They can be concisely described as diagrams "representing pictorially relations among sets" (Sneddon, 1976, p. 606). This can be more loosely stated as *Venn diagrams are representations of the relations between particular classes of concepts.*

Venn diagrams have been used in a variety of educational contexts: as illustrations of the partitioning of overlapping variance, in texts on research methodology (e.g., Burroughs, 1975; Kerlinger, 1973), as an illustration of the shared and unique characteristics of three teaching styles according to 23 observed behaviors (Eggleston, Galton, & Jones, 1976, p. 65), as a method for the analysis and classification of language used in writings about curriculum innovations (Rice, 1978), as a tool to enable greater precision in specifications for on-line computer literature searches (Smith, 1976), as an approach to the study of dinosaurs (Dudley, 1977), as a teaching strategy in chemistry (Henson & Stumbles, 1977; Leisten, 1969). These examples of the wide variety of contexts in which Venn diagrams have been used serve to illustrate their potential to represent concisely relations

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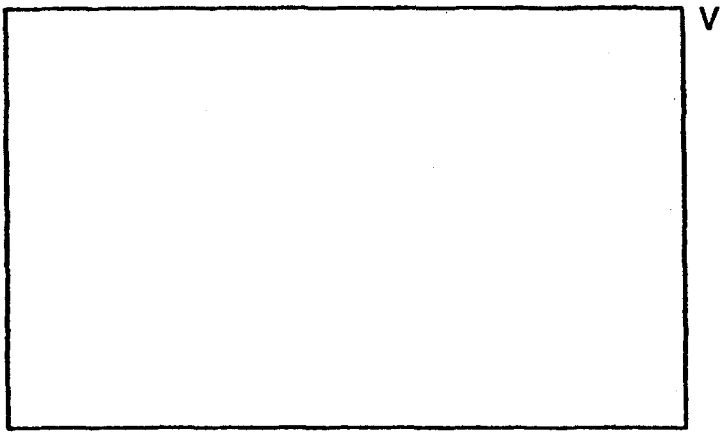
Below, the set V = {motions with changing velocity} is shown.

On this Venn diagram, show the following sets:

C = {motions with constant, but not zero, acceleration}

D = {motions with changing acceleration}

(label the sets clearly to show which is which)



Now, on the Venn diagram,

(a) mark the point which represents "motion of a ball bearing dropped from a height of 2 metre" and label it "A",

(b) mark the point which represents "motion of a man who falls from an aeroplane flying at 5000 metre" and label it "B".

Figure 1. An example of a Venn diagram question involving kinematics concepts and events.

between concepts. It seems a small step from these uses to the construction of Venn diagram questions aimed at revealing something of the way in which individuals see particular concepts to be related. Nevertheless a thorough literature search revealed no such previous usage other than that of Gunstone (1980b), although the testing potential was hinted at indirectly by Leisten (1969).

Gunstone (1980b) used Venn diagram questions to probe aspects of the understanding of kinematics and dynamics concepts among senior high school physics students. As the students involved were familiar with Venn diagrams and set notation, the questions were administered as a pencil and paper task to whole classes without an explanation of the format of the task. Where familiarity is absent, more everyday language would better be used in the question than the rather formal notation that Gunstone used. Figure 1 shows one of Gunstone's questions, and Figure 2 shows three selected student responses.

In teaching or in testing, the production of the diagram can be followed by a request for an indication of where specific examples should be placed, as shown in Figures 1 and 2. There could also be requests for examples of objects or phenomena in regions of the diagram.

The examples of student responses in Figure 2 indicate the nature of the information that is obtained from Venn diagram questions when administered to a group. Response (a) in Figure 2 suggests that this student sees the relation between the concepts of changing velocity, constant acceleration, and changing acceleration in much the same way as does a physicist. Response (b) indicates, among other things, a substantial lack of precision in the relations perceived by this student. The response suggests that motions can have both constant and changing accelerations. The notion that this response may arise from considering one motion as exhibiting both constant and changing acceleration (e.g., motion of a man who falls from an aeroplane flying at 5000 m) is difficult to accept given the placement by this student of events A and B in set C. Whether or not response 2(b) shows a view of changing velocity sometimes occurring when acceleration is neither constant nor changing cannot be determined. It may be that this space on the response

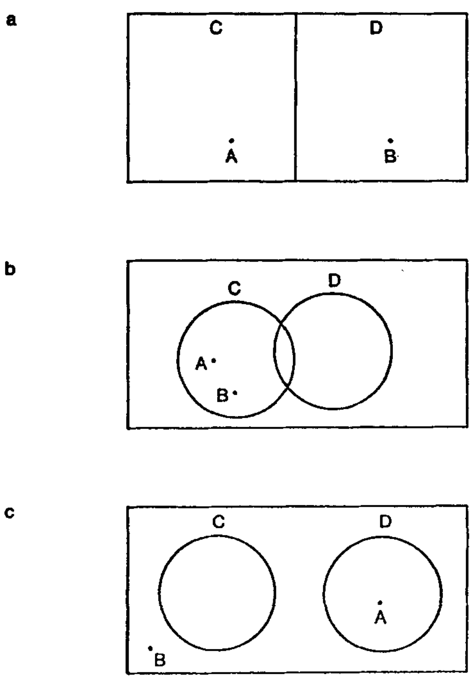


Figure 2. Three examples of responses to the question shown in Figure 1.

was seen by the student to be the null set. However such a view of changing velocity is clearly shown in response 2(c), where event B has been placed within set V but not within set C or set D. We have found some physics graduates in preservice teacher training who express this view of changing velocity occurring without constant or changing acceleration. Some of these graduates have been ready to defend their position, although hardly convincingly.

Questions of this form are useful in a wider context than as group tests given to students familiar with set notation. The brief discussion above of response 2(b) raised a number of questions that could appropriately have been asked of the student producing the response. Venn diagram questions may be useful as stimuli in interviews, providing even more powerful probes of understanding than when used in a group test.

This consideration of response 2(b) points to a major issue in interpreting responses to this or any other form of group test. If the reasoning used to arrive at the response is not elicited, then it can only be inferred from the response itself. Such an inference will not always be correct. For example, in a year 7 science class that one of us is teaching, students were testing a number of substances for solubility in water. One substance was sodium chloride and came from a bottle carrying that name. A student volunteered that he knew this substance would dissolve. He was asked how he knew and replied "because it's got chlorine in it and chlorine dissolves in swimming pools." A correct answer was derived from incorrect (and unexpected) reasoning. For Venn diagram questions, it is important then to know why respondents construct the diagrams they do. In the study in which the question shown in Figure 1 was used, a number of related questions were given and consistencies across questions looked for, so that the logic used by respondents could be inferred with some confidence. In an interview context one can ask directly for the reasons underlying the way the respondent maps the given sets.

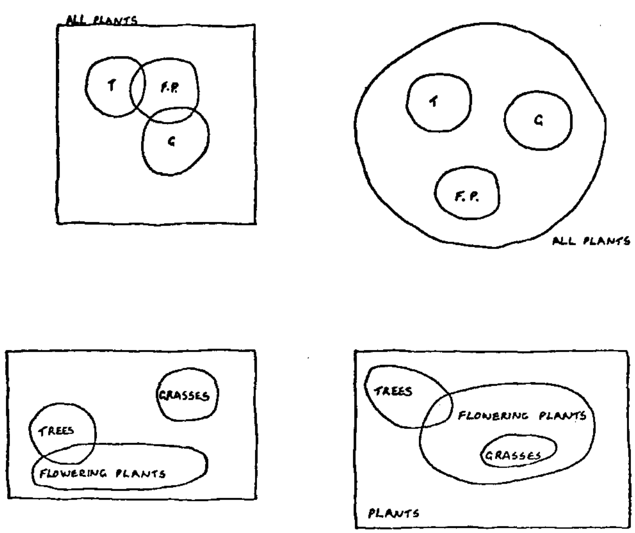


Figure 3. Examples of Venn diagrams produced by science graduates for the sets All plants, Flowering plants, Trees, Grasses.

Whether as group tests or interview probes, Venn diagrams are readily used with students who do not understand set notation. Under these circumstances, the task is expressed in a form such as "draw a diagram to show the relations you see between these concepts/ideas." Depending on the sophistication of the respondents, it may also be necessary to work through an example to illustrate the intent of the instructions. This is particularly so for respondents unfamiliar with the structure of the formal logic involved in the production of Venn diagrams.

Some responses from science graduates in pre-service teacher training to one Venn

TABLE I
Examples of Sets for Venn Diagrams

Bases	Elements	Animals
Hydroxides	Compounds	Plants
Alkalis	Metals	Micro-organisms
	Non-metals	
Carbon compounds	Amphibians	Properties of light
Organic compounds	Frogs	Properties of waves
Ionic compounds	Reptiles	Properties of particles
	Crocodiles	
All collisions		
Collisions where momentum is conserved		
Collisions where kinetic energy is conserved		
Moving objects		
Stationary objects		
Objects having work done on them		
Objects having no work done on them		
Objects having work done on them		
Objects with changing kinetic energy		
Objects with changing potential energy		

diagram question are shown in Figure 3. The question required them to represent the relations between all plants, flowering plants, trees, and grasses. Variations of the top left answer were the most common response.

Examples of appropriate follow-up questions to use with this group of concepts include: Where would you place conifers on your diagram? Where clover? Where bamboo? Give an example of a plant in each of the regions shown on your diagram.

Our experience with Venn diagram questions suggests that these tasks work best when they involve from two to five terms. Of course the concepts must be of similar type, otherwise it will be difficult or even impossible to draw a meaningful diagram. Examples of inappropriate groups of concepts are element, atom; mammal, egg, water; botany, acid, force.

Table I contains examples of sets that could be useful. Most of these groups of concepts are based on class inclusion relationships such as A is a subset of B, B a subset of C, and so on. Certainly the methodology lends itself to this specific form of concept–concept relationship. However, variations on this theme are also possible. The example discussed in the next paragraph involves two related dichotomies rather than a single hierarchy of inclusion.

As with any questions asked of students, the amount of information given in a Venn diagram task can be varied in order to provide a specific focus. For example, one item used by Gunstone (1980b) involved the sets objects that are moving, objects that are stationary, objects that have no resultant force acting on them, objects that have a resultant

Below, the sets M = {objects which are moving}

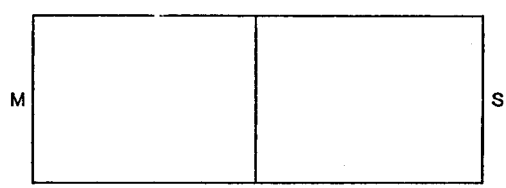
and S = {objects which are stationary} are shown.

On this Venn diagram, show the following sets:

Z = {objects which have no resultant force acting on them}

R = {objects which have a resultant force acting on them}

(label the sets clearly to show which is which)



Now, on the Venn diagram,

(a) mark the point which represents "car moving at constant velocity" and label it "A".

(b) mark the point which represents "car accelerates" and label it "B".

Figure 4. A Venn diagram question with additional information given.

force acting on them. The question was given with two of these sets already shown, as in Figure 4. This was done to have the question focus specifically on the relations between resultant force and motion. In so doing it may reveal, for example, students who see motions through Aristotelian glasses. At a more subtle level it can also indicate whether or not students have included in their relations issues such as objects with a resultant force acting on them being instantaneously at rest. A later question in the test involved the sets objects moving with constant, but not zero, velocity, objects moving with changing velocity, objects that have no resultant force acting on them, objects that have a resultant force acting on them. The combination of data from this question and the question shown in Figure 4 gave a comprehensive picture of the relations seen between force and motion.

We conject that Venn diagrams may provide a way of assessing aspects of attitudes, although we have not formally used Venn questions for this purpose. Consider the pair of items open classrooms, places of learning. An extreme response that shows no overlap between the two items leads to the inference that the respondent has negative attitudes about open education. Other examples of items dealing with attitudes are: scientists, science teachers, naturalists; useful knowledge, physics principles, chemistry principles.

As with other probes of understanding, Venn diagrams are useful as a teaching technique. One of us has used them quite extensively in teaching physics. Answering a Venn diagram question can promote useful introspection and show students the way in which they have conceptualized relations. Venn diagrams can be powerful stimuli to discussion and may result in easily remembered image-based summary statements.

We have argued that Venn diagrams are powerful probes of students' understanding of the meanings of terms and the relations between concepts. Among other important properties are that they take a short time to complete, can be used with classes of any size and with students at any level from mid-elementary school upwards, and their nonverbal form can expose vagueness in conception that may be disguised in verbal responses. (The inverse of this last point may also be true in some cases: the precision of the diagram could disguise imprecision in the thinking underlying the diagram.) These properties should lead to extensive use of Venn diagrams as an additional mode of probing understanding, both in research and classroom practice.

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