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ASSESSING MIDDLE SCHOOL STUDENTS'
UNDERSTANDING OF SCIENCE RELATIONSHIPS AND PROCESSES:

Final Report

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ASSESSING MIDDLE SCHOOL STUDENTS'
UNDERSTANDING OF SCIENCE RELATIONSHIPS AND PROCESSES:
Final Report

Our overall goal for this multi-year project is to develop and validate an alternative assessment format that effectively measures middle school students' understanding of the relationships among selected science concepts and processes. In this project, we collaborate with the staff of the Los Alamos National Laboratory's TOPS Program and the Program's participating teachers and their students. We also work with selected middle school science teachers from the TOPS program at Sandia National Laboratories.

Our goal for this past year was to develop and field test informally a variety of potential measurement formats. This work has allowed us to identify formats to test during the validation phase of the project which will occur during the second year.

This document summarizes our progress from the first year of the project. It includes three major sections. The first is a report that synthesizes the literature we used as background for our work, describes the development of our assessment formats, presents the results and conclusions from our informal testing of these formats in TOPS teachers' science classrooms, and summarizes our proposed activities for the validation phase of the project. The second section contains a bibliography of much of the literature we read. The last section, contained in appendices, includes a copy of each assessment format we developed and tested.

Mental Networks

We realized that we needed a model of learning to guide our thinking about assessment. We based our model on the theoretical assumption that students form mental networks in the process of learning. We defined meaningful learning as the accurate interrelating of concepts in students' mental networks, also called their cognitive structures. This type of understanding often is called structural knowledge (Jonassen, Beissner, & Yacci, 1993). It includes not only the concepts (referred to as nodes and often represented visually in ovals or rectangles) but also the connections (referred to as links and often represented with arrows) that interrelate them. A proposition, which consists of two nodes connected by a link, is the basic unit in structural knowledge. For example, the proposition "magma heats underlying rock" consists of the concepts of "magma" and "underlying rock" connected by the link "heats." For additional information, see Novak and Gowin, 1984.

Current thinking about the science curriculum in K-12 schooling is increasingly concerned with structural knowledge. This concern is reflected in the on-going work on national standards and goals in our country. Science for All Americans (Rutherford & Ahlgren, 1990) and Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) emphasize "interconnections," "connectedness,"

"coherence," "themes," and "relationships" within science and among science and other disciplines. In fact, the development of the benchmarks relied extensively on backmapping, a mapping technique that was used to link antecedent ideas to literacy goals for adults. Similarly, the NCTM Curriculum and Evaluation Standards for School Mathematics (1989) explicitly contains a standard for each set of grades called "Connections" (standard #4). The connection standard for Grades K-4 includes outcomes such as "link ... knowledge" and "recognize relationships" (p. 32). For Grades 5-8, desired outcomes include, for example, "see mathematics as an integrated whole" (p. 84). For Grades 9-12, outcomes include, for example, "use and value the connections among mathematical topics" and "use and value the connections between mathematics and other disciplines." (p. 148). These emphases on connections found in our emerging national goals illustrate the importance associated with students' acquisition of structural knowledge in science and mathematics.

Desired Assessment Characteristics

We need a valid measure of students' connected understanding, or structural knowledge, that will complement, not replace, traditional and alternative types of assessments of achievement used in school-based research. Ideally, our measure could be administered efficiently (in less than one class period) to a class as a whole. We do not want to depend on computers for administration or scoring, since many classrooms do not have the needed hardware or software. We want a measure that shows the students a visual structure as they complete the assessment; this exposure may assist students in their learning. This structure should contain labelled nodes and links since both are critical in meaningful learning. Finally, the assessment technique should yield at least one valid interpretable score that explicitly quantifies structural knowledge.

Structural Knowledge Assumptions

We have five assumptions about structural knowledge that form the basis for our assessment work. These are based on theory and research and include the following:

1. Students learn meaningfully through assimilating structural knowledge, not through learning isolated facts or concepts.
2. Students can construct explicit characterizations of their cognitive structures.
3. Students can understand and learn from adequate characterizations constructed by others of the structural knowledge implicit in materials.
4. There are communalities among adequate characterizations of structural knowledge within a subject area.
5. In order to perform tasks requiring higher order thinking skills, students must possess adequate and relevant structural knowledge.

Structural Knowledge Assessment Techniques

There are a variety of techniques available to use in assessing the structural knowledge of students. In this section, we present selected examples of these techniques and a synthesis of the literature involving them. This information comes from three bodies of literature emphasizing concept-relatedness, concept mapping, or other visual-spatial techniques. Surprisingly, these three areas are not well interrelated; that is, research in one area often does not acknowledge research done in another.

Concept-relatedness techniques

These techniques are accepted as valid for measuring students' structural knowledge, at least at the post-secondary level. They are the "traditional" structural knowledge assessment techniques.

These techniques usually involve first obtaining (or eliciting) students' structural knowledge indirectly, often through the use of word associations or paired similarity ratings of concepts deemed important by one or more experts (usually instructors). Naveh-Benjamin, McKeachie, Lin, and Tucker (1986) developed a variation of the word association approach called the ordered tree. Students are given a set of concepts characterizing the discipline under study; they arrange these concepts in a list such that the ones whose meanings are most closely interrelated are placed near each other. Students complete the listing task four times, with breaks between each repetition of the task. Using another approach, Goldsmith, Johnson, and Acton (1991) developed a measurement technique based on similarity ratings. Students rate the degree of connection or "relatedness" between pairs of concepts, each selected from a list of about 60 concepts.

Both of these approaches yield a matrix for each student that contains numbers representing that student's "cognitive distance" between each pair of concepts. Based on these distances, the student's structural knowledge is characterized both visually (in the form of a map) and numerically (as scores indicating the adequacy of the map, often in comparison to an instructor-drawn map). Both characterizations are obtained through computer software programs, such as Pathfinder, that analyze these cognitive distances. The resulting output consists of a visual pattern of concepts connected by unlabeled links. The person examining these patterns can label the links, but the learner who completed the assessment task does not do so.

Concept-relatedness techniques have been used primarily by researchers, often experimental psychologists, interested in studying cognitive structures. In fact, the use of these techniques for research is the reason that good validity evidence about them exists. There are at least three research findings that provide evidence of the validity of these techniques. First, scores obtained from these techniques are moderately related to achievement measured in more traditional ways (e.g., usual classroom tests). This finding indicates that these measures do assess achievement, but it is achievement of a

different kind than that assessed by traditional measures. Second, with increased learning, students' structural knowledge becomes more like that of their instructors. Third, there is more agreement about structure among instructors than among students. See, for example, Acton, Johnson, and Goldsmith, 1994; Goldsmith and Johnson, 1990; and Naveh-Benjamin, McKeachie, Lin, and Tucker, 1986. The major advantage of these word association and similarity rating techniques is that they have been accepted as valid measures of structural knowledge.

We eliminated concept-relatedness techniques from consideration as our selected structural knowledge measure for the following reasons. First, they require unique computer software for analysis (and often are administered using computers, although they do not have to be). Second, it is unlikely that students learn anything in the process of doing word associations or ratings, nor do they see their maps as they complete the task. We expect that it might be difficult to convince some students to do these tasks. Third, even though the results can be presented in a map, the links in the map are unlabeled; labelled links are an important part of meaningful learning. Fourth, although these techniques may work with students of all ages, published research using these approaches has involved only college students. Fifth, these techniques lack "face" validity; that is, they do not look like they measure something as important as structural knowledge. Because of this problem with appearance, it might be difficult to convince teachers to allow researchers to use these kinds of tasks with their classes.

Mapping techniques

Structural knowledge can be presented visually in a number of ways, often in the form of some kind of map. Mapping techniques are used for at least three instructionally-related purposes: in learning, in instructional development, and in assessment (Harnisch, Sato, Zheng, Yamagi, & Connell, 1994).

First, they can be a learning tool. They may be prepared by an "expert" like the teacher and then shared with students with the intent of portraying the experts' structural knowledge to help the student learn (see, for example, Cliburn, 1991; Dansereau, 1994; and Holley & Dansereau, 1984). They also can be created by students as part of the learning process (e.g., Novak & Gowin, 1984; Novak & Wandersee, 1994). There is a growing body of research indicating that both of these uses assist some students in learning (e.g., Clarke, 1991; Horton, McConney, Gallo, Woods, Senn, & Hamelin, 1993).

Second, mapping techniques can be used as instructional planning and curriculum development tools. Teachers can use mapping in designing (a) content coverage materials (such as handouts and notes), (b) sequence of instructional delivery, and (c) delivery strategies (such as activities and presentations). Drawing these maps forces the creator to identify important concepts and the ways they are interrelated and to make explicit any implicit mental characterizations. Mapping techniques also are very useful to teachers and curriculum planners in organizing overall connections in

content (American Association for the Advancement of Science, 1993; Starr & Krajak, 1990).

Third, these mapping formats are used to assess students' structural knowledge by researchers (e.g., Chi, Hutchinson, & Robin, 1989; McKeown & Beck, 1990; Novak & Musonda, 1991) and by classroom teachers (e.g., Novak & Wandersee, 1994). Unlike the relatedness measures of structural knowledge, concept maps actually look like they measure connected understanding. In addition, they do not require computers for administration or scoring, and they yield labelled links.

Perhaps the most widely known, and inclusive, of these formats is the concept map. Novak and Gowin (1984) developed this technique for research and evaluation purposes. In their early work, students were interviewed about their understanding of science; the interviewers then characterized students' structural knowledge by drawing a concept map containing the students' concepts and (labelled) links. See Novak and Musonda, 1991.

Since that time, concept maps that have been drawn directly by learners have been used as measures of structural knowledge. Students arrange important concepts into a map and connect them with links they label. They either generate their own concepts or use concepts that are given to them in this process. This work can be done individually or in groups.

Good concept maps include enough important concepts to characterize the subject, and these concepts are clearly linked with important relationships. These propositions often are grouped into neighborhoods (clusters of concepts that are more closely interrelated with each other than with other concept clusters). For example, Figure 1 (which served as the basis for one of our assessment formats) includes three neighborhoods. The one on the left characterizes the natural production of geothermal energy. The neighborhood in the middle of the map is a feedback loop describing the renewable aspect of geothermal energy. The linear neighborhood to the right characterizes the process that yields useable power from geothermal energy. These neighborhoods may be cross-linked with each other. In Figure 1, for example, the "water" node in the feedback loop neighborhood is cross-linked to the "mixture of underground water and steam" node in the natural production neighborhood.

Novak and Gowin (1984) first developed a quantitative scoring system for these maps. Points are awarded based on map characteristics, including number of correct propositions, levels of hierarchy, cross links, and examples. Alternative scoring schemes have been suggested by others, including Morine-Dersheimer (1989), Anderson and Huang (1989), and Liu (1994).

There is growing research evidence of the validity of concept mapping as a measure of structural knowledge. As would be expected, the maps of experts are large, more complex, and more connected, especially across neighborhoods, than those of

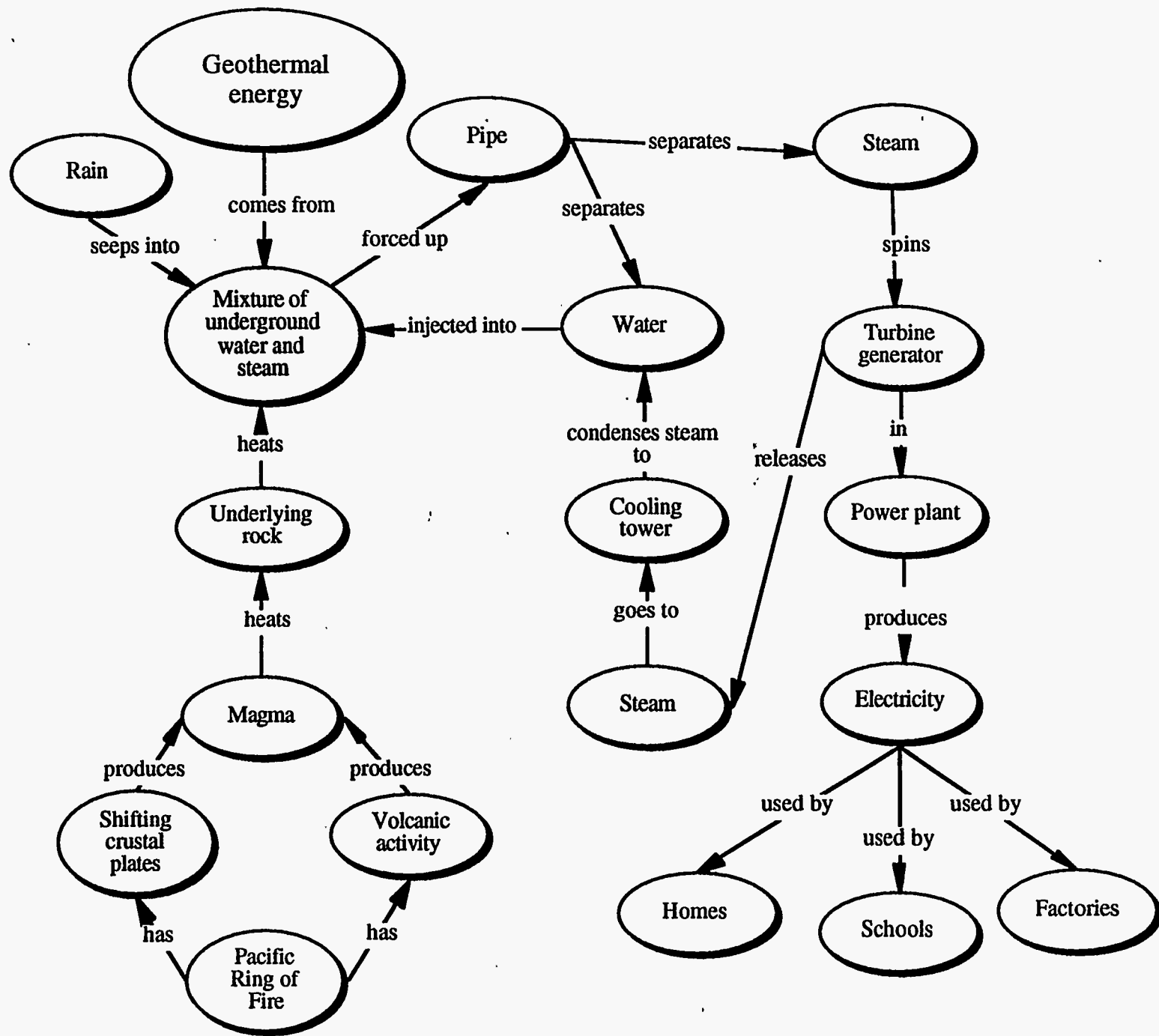


Figure 1. Example concept map describing geothermal energy.

novices. Like relatedness ratings, the structure of students' knowledge as assessed by concept maps becomes more like those of experts with increasing educational exposure. See, for example, Liu, 1994; Markham, Mintzes, and Jones, 1994; Novak and Ridley, 1988; and Wallace and Mintzes, 1990.

Concept maps do have limitations as classroom-based research assessment measures. First, the concept map generation process is time consuming and yields idiosyncratic maps since there are many correct (and, of course, incorrect) ways to characterize any set of concepts and their interrelationships. Second, there is no universally accepted and simple scoring system for concept maps. Third, students must learn to draw concept maps. The process of creating these maps can be tedious and frustrating, since it often takes several revisions before arriving at an adequate map. The research also indicates that some students (and instructors) do not like to draw concept maps (see, for example, Barenholz & Tamir, 1992).

Fill-in formats

Any map design can be used as a fill-in assessment measure. The general process involves constructing a master map. Keeping that map structure intact, some or all of the concept and/or relationship words or symbols are omitted. Students fill in these blanks either by generating the words to use or by selecting them from a set which may or may not include distractors. The selection set may be listed on the map itself. Naveh-Benjamin and Lin (1991), for example, used a variation of this approach with ordered tree structures. Post-secondary students are given a hierarchical graphical characterization of an expert's ordered tree with up to 50% of the concepts left blank. Students select the best one to fill in each blank from a list of these concepts. Surber (1984) may have been the first to use a fill-in approach.

These fill-in formats can be made-simple or more difficult. Harder assessments are created by constructing more complex master maps, by omitting more words, and/or by omitting words that are close to each other on the map.

Fill-in formats can yield several kinds of scores. The easiest to obtain (and most similar to the scoring of traditional types of items) is number of (or percent) correct responses. Several types of scores can be obtained from students' incorrect responses; these may be more interesting from a structural knowledge perspective. For example, these include scores that characterize the degree of response misplacement in the structure.

Because fill-in formats have been used infrequently in research, there is minimal evidence of the validity of this approach. Like the scores resulting from the traditional concept-relatedness techniques, our work provides some evidence that number of correct responses to fill-in formats is moderately related to multiple choice test scores.

These formats have several useful features. They can be administered relatively

quickly and to groups of students. They do not require a computer for administration or scoring, although computers can be used for these purposes. It is easy to obtain and interpret a percent correct score, and other scores are available. Fill-in assessments may well involve a learning component since students see the map structure as they complete the task.

Classroom Data Collection

At the 1993 fall TOPS workshop, we asked the TOPS teachers to provide us with some feedback about two possible designs for our assessment formats. Both required filling in blanks in maps, but one map resembled a concept map while the other was in a matrix format. Based on teacher responses, we decided to concentrate on testing the concept map design.

We then worked with TOPS students and teachers at three different sites: Estancia, Cuba, and Taos. Our goal was to evaluate a number of different assessment formats and select one or two for validation work during the second project year.

We worked with groups of three to six students at Estancia and at Cuba; each of us led one group per class period. At Taos, each of us worked with one student. The procedures at each site were similar. First, we introduced ourselves and the purpose for our project. Second, we introduced the idea of concept maps, using a simple example we developed. Third, students viewed the first six minutes of a video called *Geothermal Energy: A Down-To-Earth Adventure*; we used the video to ensure that each student was exposed to the information required for potential successful completion of their map assessment formats. Fourth, the students and leaders completed an example that matched the format that the students would attempt. Fifth, each student completed the format independently (although there often was collaboration among group members); at Estancia and Cuba, the students did their work silently while at Taos each student was asked to "think out loud." Sixth, at Estancia and Cuba, the students and leaders discussed the students' responses to the formats as a group; at Taos, individual students answered questions about their thinking processes, difficulty level of the task, selected correct and incorrect answers, and vocabulary. Finally, we thanked the students and teacher for their help.

Our map assessment formats varied based on two primary characteristics: the design of the map itself and the type of response required from the student to complete the map. All of our formats required students to respond either by selecting or by generating their answers. All but one of the designs included maps with only nodes missing, only links missing, or both nodes and links missing. In the remaining design, the whole map structure missing, and the students were to generate a structure using the given concepts. This latter design corresponds to one traditional way that concept mapping has been used. Table 1 describes the formats used in Estancia, Table 2 those used in Cuba.

Table 1. Map designs and types of responses used at Estancia.

Map elements missing	Select responses	Select responses with distracters	Move responses	Generate responses
All nodes	yes	yes	yes	yes
All links	yes	yes		yes
50% nodes	yes	yes		yes
50% links	yes	yes		yes
Non-consecutive nodes & links	yes	yes		yes
Some consecutive nodes & links	yes	yes		yes
Structure	yes		yes	

Table 2. Map designs and types of responses used at Cuba.

Map elements missing	Select responses	Move responses	Generate responses
Non-consecutive nodes & links	yes		yes
Some consecutive nodes & links, complex map	yes	yes	yes

Estancia Middle School

At Estancia Middle School, we worked with Jeff Dulaney and about 110 of his seventh and eighth grade students in five class periods. Our goal was to try out all of the concept map assessment formats that might be useful in assessing students' structural knowledge.

We developed and informally tested 21 map assessment formats (see Table 1); a copy of each is included in Appendix I. In the select response type, students selected from a list of responses found on their map formats, with some lists containing only the responses needed and some containing the correct responses and distractors (selections that were never correct), or moved responses contained on "puzzle" pieces around the spaces on their maps until they decided where best they fit. The table indicates what percentage of nodes and/or links were omitted from each map format design. In the format called "non-consecutive nodes & links," we did not eliminate consecutive nodes and links; in "some consecutive nodes & links," we eliminated some consecutive nodes and links while others that were eliminated were embedded in information.

Some of the following results were expected and some were not. Briefly, our results indicated:

- (1) Students understood and all attempted to do our map assessment formats.
- (2) Three of our designs ("all nodes," "all links," and especially the generate "structure" from the given concepts) were too difficult, and students often gave up on these. The latter design asked students to draw their own concept maps from a list of nodes they were given, and this task required more training and time than we were able to give in one class period.
- (3) The "50% nodes" design was too easy.
- (4) The "select responses with distractors" response type often doomed students to failure. If they chose a distractor early in the process of filling in their maps, this choice often made the map format much more difficult than it was. That is, they had trouble filling in the rest of the map in a way consistent with the error caused by the distractor. In addition, we realized that including distractors would create difficulties with some of the scoring systems we were considering.
- (5) The "select" and "movable" responses were easiest to score by computer.
- (6) The "non-consecutive nodes and links" and the "some consecutive nodes and links" designs with the "select" or "move" responses were the most promising formats.

Based on these results, we eliminated the response types that included distractors

and that required the creation of a structure. We also eliminated the map designs missing either all nodes or all links. In addition, we also eliminated the "50% nodes" design.

Cuba Middle School

At Cuba Middle School, we worked with Peggy McCracken and about 100 of her seventh and eight grade students in four classes. Our goal was to test fewer selected map assessment formats with the goal of eliminating all but one or two. We continued to test three types of responses: selecting responses from a list, selecting responses by moving puzzle pieces into place, and generating responses. We tested two map designs, including the non-consecutive missing nodes and links and a more complex design with some consecutive missing nodes and links; see Table 2 and Appendix II.

Our results indicated:

- (1) Missing node-link consecutive combinations tended to be harder than isolated missing nodes or links.
- (2) Students who were "test-wise" were able to use clues contained in the map to assist them in responding to some parts of the map; usually, they responded correctly although sometimes they were incorrect when using clues.
- (3) Although the "generate" response type has good potential for classroom use, it has three disadvantages for use in large-scale research projects. First, it depends heavily on the students' communication skills, including vocabulary, spelling, and handwriting. Second, it is not possible to identify all possible correct responses before students complete the assessment, making computerized scoring difficult. Third, different scorers will disagree about what responses should be counted as correct; a group of experts would have to make these decisions after a list of all responses to each blank in the map had been tallied.
- (4) Careful map design is critical. We unintentionally included a few blanks in our maps that could be filled correctly by more than one response (e.g., "water" for "rain").
- (5) The more complex map design with some consecutive and some isolated nodes and links missing that require selecting responses either from a list or from the movable pieces is about the appropriate level of difficulty for seventh and eighth grade students. On the average, these students responded correctly to about half of the 12 blanks. We found no statistically significant differences in percent correct scores based on gender, ethnicity, or select response type (from a list or using moveable pieces). The gender and ethnicity findings are positive ones but very preliminary due to our small sample size (about 35 students).

(6) Students seemed to approach the task of doing these assessments in many different ways, even when given identical instructions.

Based on these results, we selected the most complex map design using the response tasks of selecting from a list and from a set of movable words to continue to study.

Taos Junior High School

At Taos Junior High School, we worked with Francisco Romero, a former TOPS teacher, and 12 sixth, seventh, and eight grade students. Our goal was to examine in detail the cognitive skills used by students in completing our map assessment formats. For this reason, we asked students to talk aloud as they worked on their map. We used the most complex map used at Cuba in conjunction with selecting responses from a list or using movable pieces; see Appendix III.

Our results indicated:

(1) Different students did approach these assessment differently --

Some looked at their maps as a whole and concentrated on relationships as they worked. One of these students indicated that he "talked it out in my head to make sure it made sense." This general type of strategy is the best.

Some looked at their maps in pieces. At the extreme of this strategy, one student worked "backwards" by selecting a response from the list and then trying to locate its position on the map. This general strategy type is a poor one to use.

Some began with the "easy ones first." Some started with what they learned first. Others started at a particular point in the map and followed the arrows. Some combined more than one of these approaches.

(2) Students seemed to find the assessment task itself acceptable. Relevant student comments included:

"It was fun."

"It was a good way to learn."

"It's a better way to test."

(3) It appears that these assessment tasks include a learning component in that completing the task seems to "set" the information in the students' mental networks. Most of these students could not think of anything else contained in the video that was not on our map, a conclusion that was incorrect.

- (4) As is true with any assessment, some students missed answers because they did not have a good understanding of the vocabulary.

Conclusions and Plans

Based on our critical review of the literature and our work with students, we conclude that structural knowledge is an important part of learning and should be assessed and that map formats provide a valuable addition to the existing kinds of achievement assessments currently being used. During the second year of our project, we will further examine the validity of the map assessment format. We will use a complex map design with some consecutive and some isolated nodes and links missing that requires students to select responses from a list they are given. We reluctantly eliminated the movable pieces response types from further consideration. Although it has potential as a classroom measure, it is difficult to produce in the quantities required for large-scale research work.

During the second project year, we plan to create four complex maps. One will be an easy example designed to familiarize students with our assessment format. Of the remaining three, one each will cover an aspect of life, physical, and earth science. We will select the content for these maps through an examination of the units prepared by the teachers during the past summer TOPS Institute, the three science text series most commonly used by TOPS teachers (Science Plus Technology and Society; Merrill: Physical Science, Merrill: Life Science, and Merrill: Earth; and Science Interactions), Benchmarks for Science Literacy, and the content of the science portions of the 1989-90 NAEP and 1992 IAEP assessments (standardized tests that are used to track the achievement of our students nationally and internationally).

We will evaluate students' structural knowledge of science using at least three different types of scores obtained from these maps. These scores are based on our assumptions regarding how students learn. The percent correct score is global and contains the least amount of information about students' structural knowledge. Completed maps will also be scored based on the number of propositions that are correct. It is possible (and common) for students to choose an answer that is wrong when the map as a whole is considered but that is an acceptable response if a proposition that includes the response is considered. A second type of score, then, is the percentage of correct propositions. Finally, wrong answers can be scored to indicate whether they are placed in the correct or incorrect neighborhoods, resulting in a neighborhood score.

In order to gather validity evidence, we will relate scores on our maps to a variety of other measures of student achievement in science. We are considering standardized scores from NAEP and IAEP tests (and possibility eighth grade students' ITBS scores), teachers' grades, and measures that will indicate how much opportunity students have had to learn the material contained in our maps. Thus, information from these sources will allow us to evaluate the validity and usefulness of our approach.

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Appendix I

Estancia Map Assessment Formats and Directions

Period 1

Procedures

(have 4 extra min.: class ends 9:10)

1. Draw the example CM for energy sources on the board.

5 min 2. Talk with kids:

8:25-8:30

Introduce ourselves. Today we need your help in figuring out how students understand science. There are different ways to look at understanding, and we have developed some ways that we want to try out for the first time. Because this is the first time we have tried them out, some may be really easy, and some may be too hard. We hope that some are just fine. We just don't know yet.

We will start by showing a short video on geothermal energy.

Geothermal energy is one kind of renewable energy resource.

Here is a concept map that shows how geo. fits with other kinds:

Big gray shaded oval at the top says map is about RER.

4 kinds on this map: (list them). Each is in a gray shaded oval.

The map has an arrow coming out of RER to each kind.

Each arrow has a white rectangle that tells how RER and the energy kind are connected.

So, e.g., RER include "geothermal", also "wind", and so on.

Then the map tells us where each kind of energy comes from:

Geo. from ...

Could we have put wind first in this map? No. This piece would be right, but this piece would be wrong.

After you view video, we will ask you to put your understanding of the video into a map that looks like the one on the board:

First, each of you will do your map by yourselves;

Then your group will talk about your maps.

This isn't a test, you won't get a grade on it.

But it will help us a lot if you do your best on it.

Let's watch the video; then each group will look again at a map like this one.

6 min 3. Watch video.

8:30-8:36

5 min 4. Leaders do example.

8:36-8:41

15 min 5. Kids do their measures.

8:41-8:56

10 min 6. Group discusses.

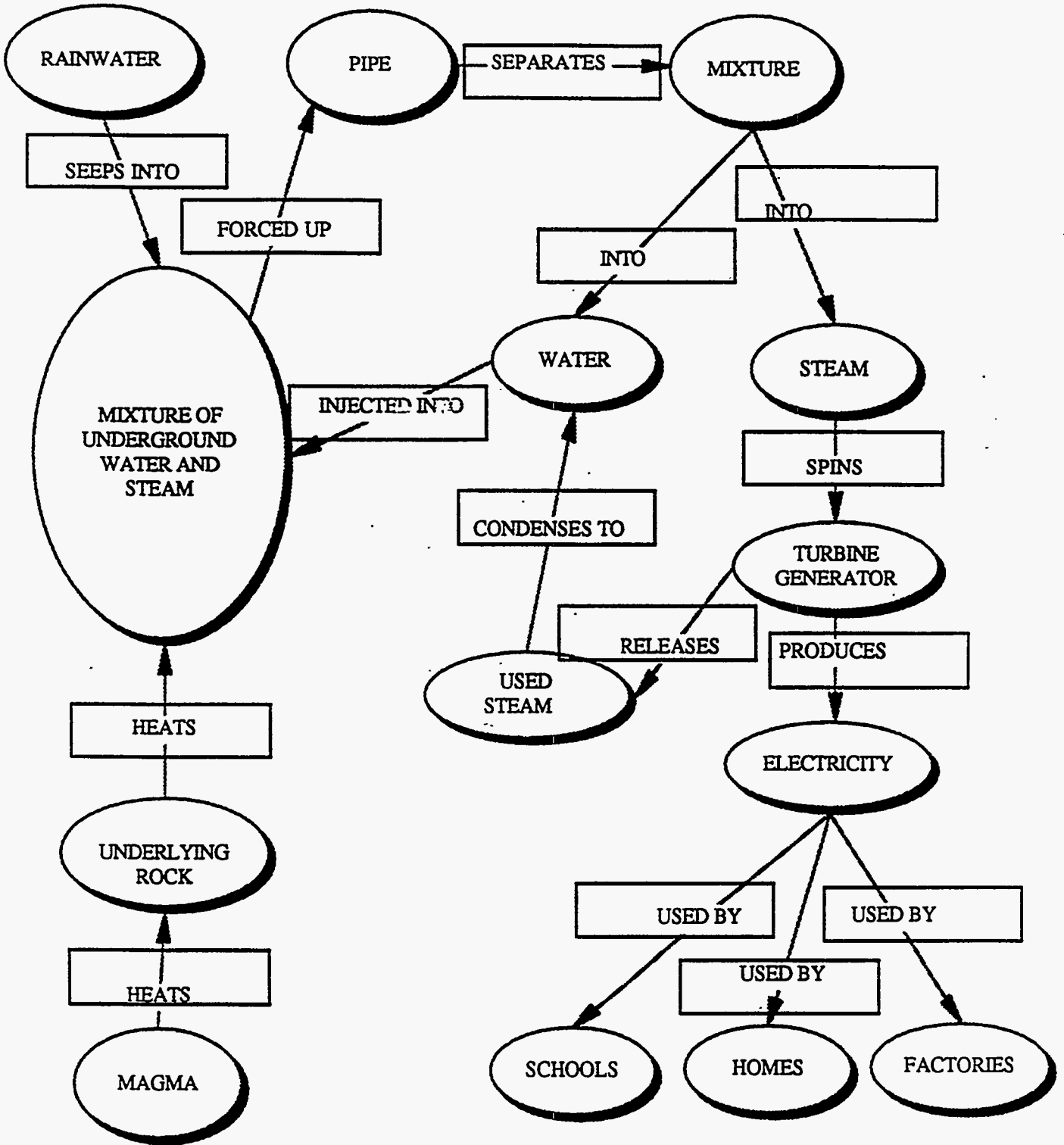
8:56-9:06

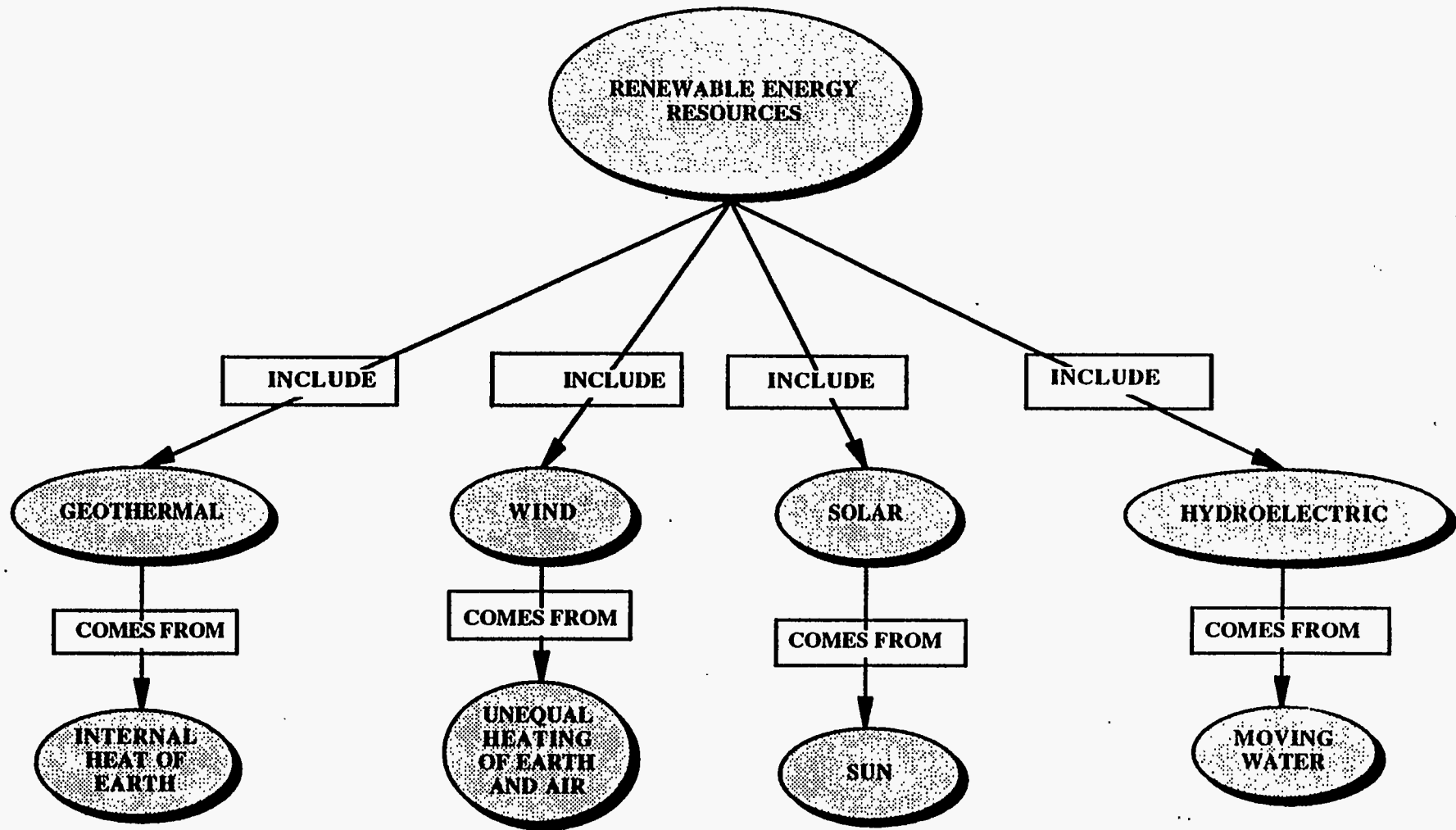
7. Thanks for your help

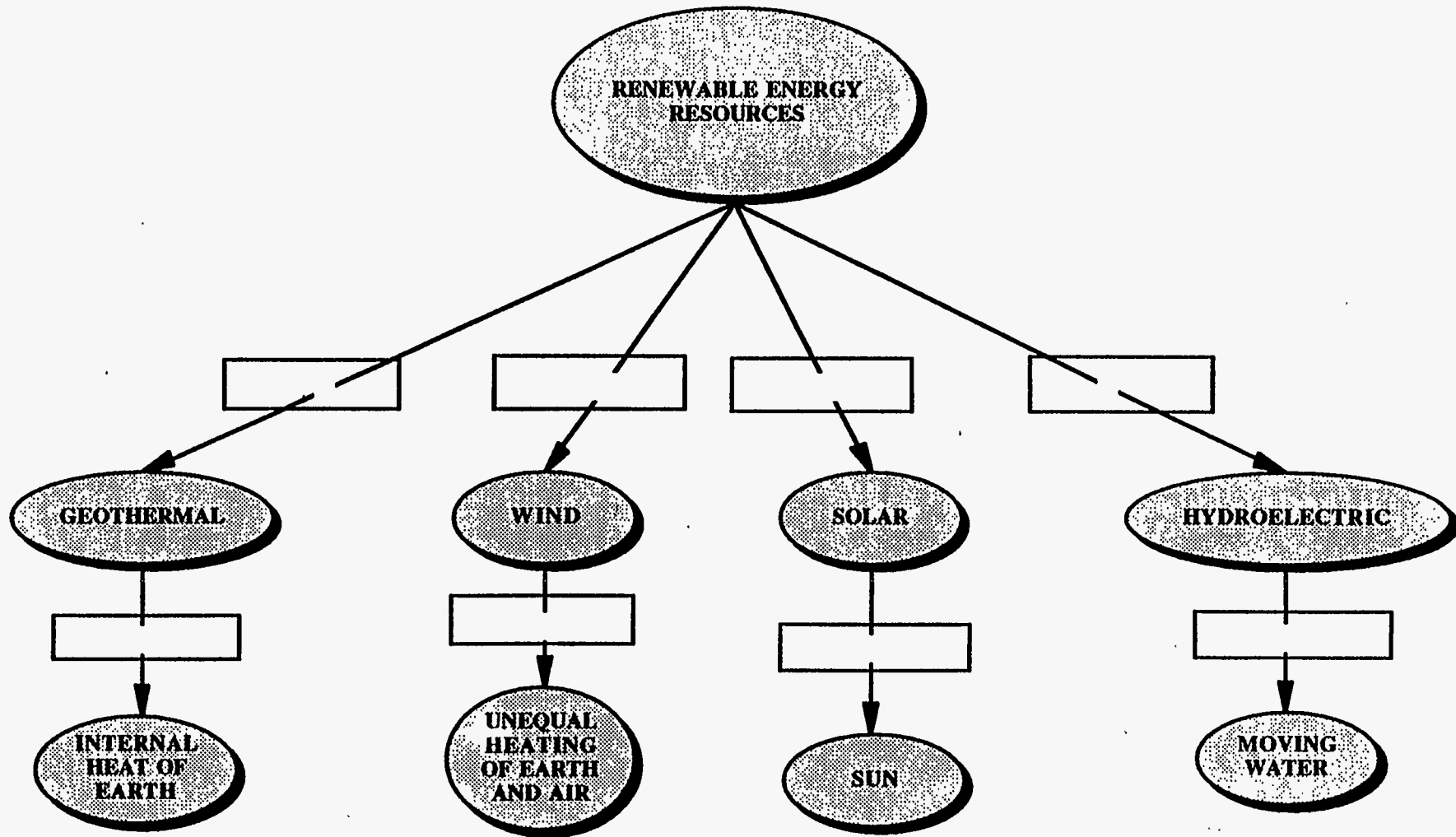
8. Journals???

insert

GEOHERMAL ENERGY



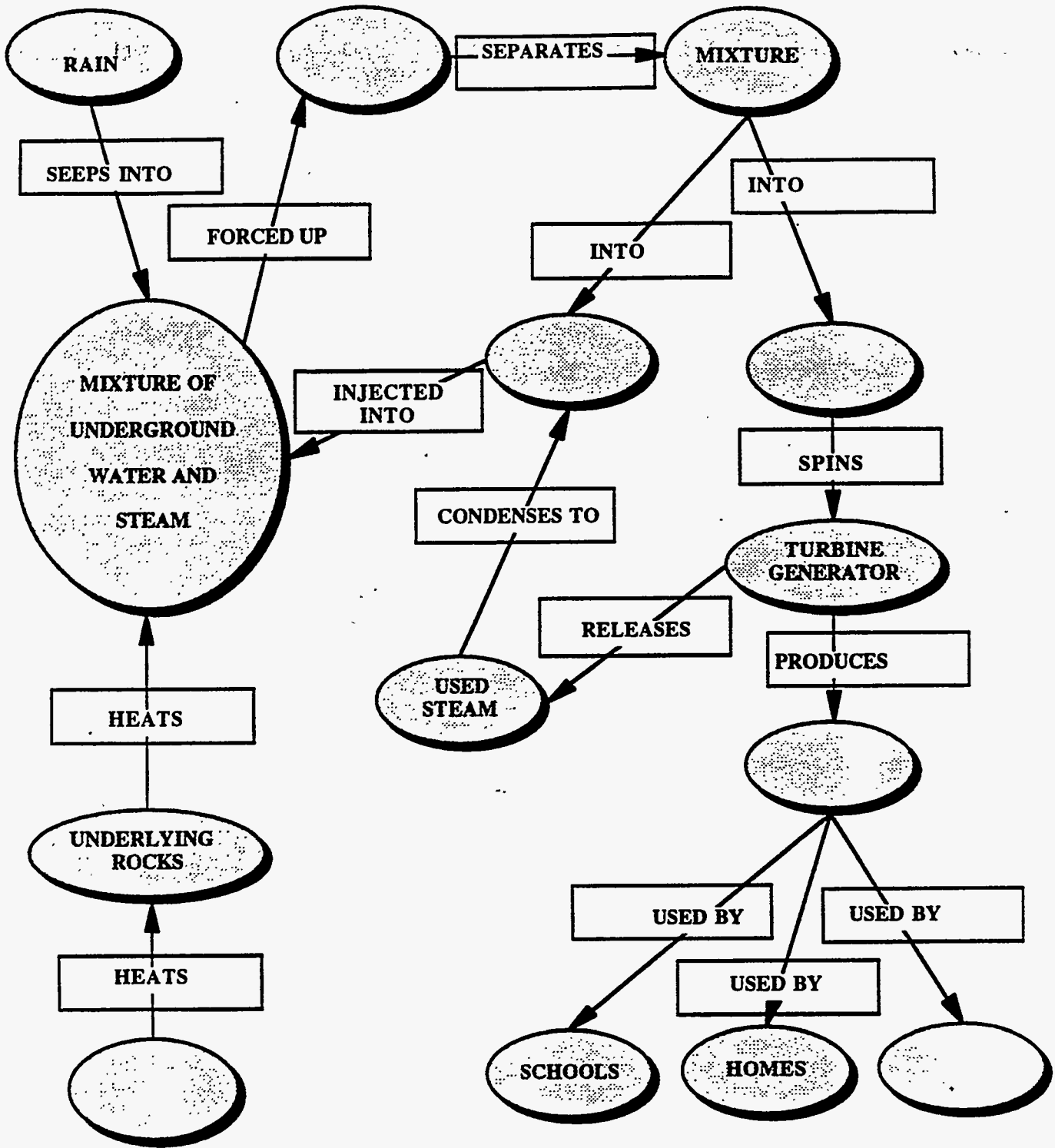




DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE FROM THE LIST BELOW.

**COMES FROM
HEATS
INCLUDE**

GEOHERMAL ENERGY



DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE FROM THE LIST BELOW.

**ELECTRICITY
PIPE
FACTORIES**

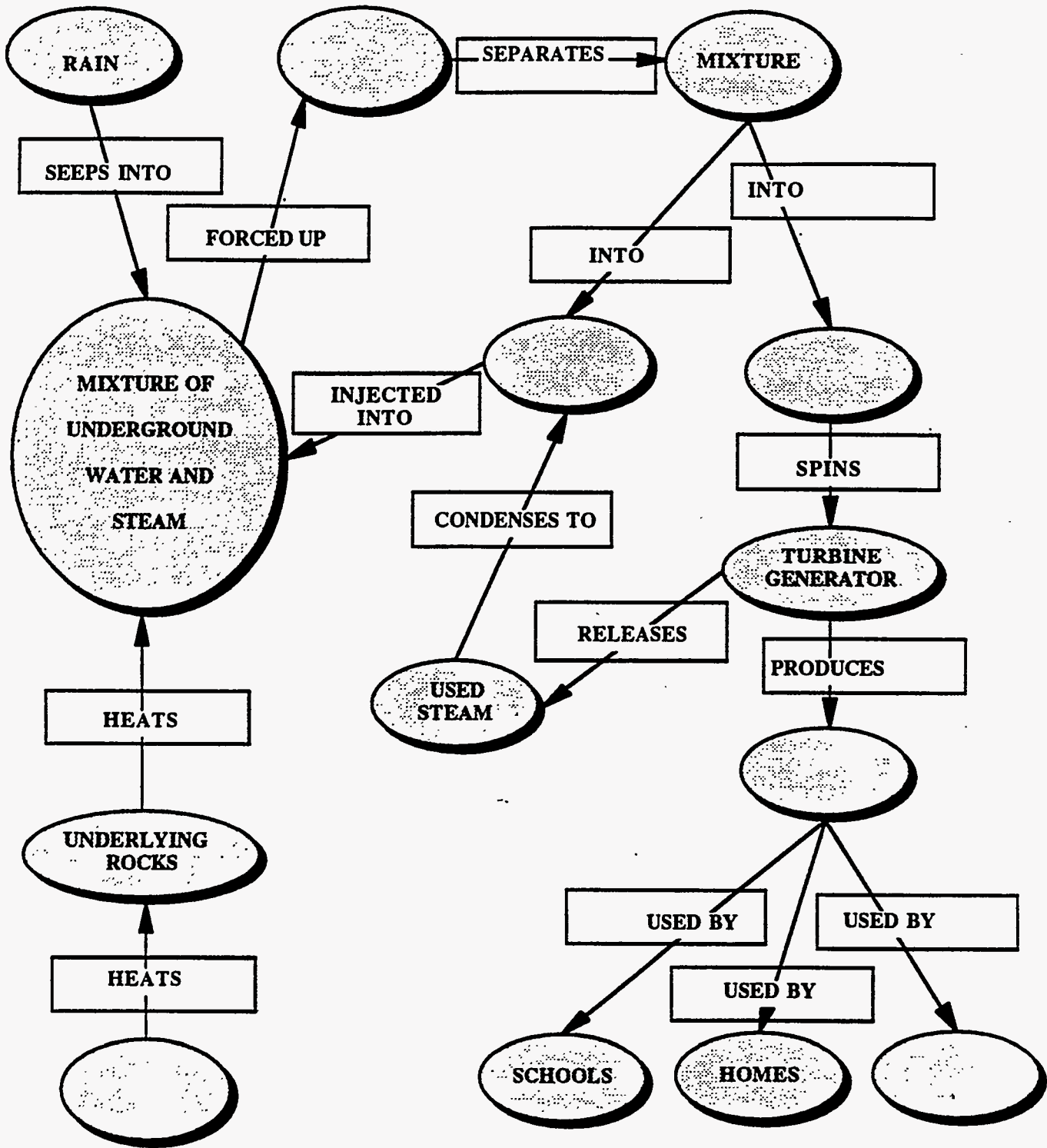
**WATER
MAGMA
STEAM**

Leader Directions: Some nodes, fill-in

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) The missing concepts are listed at the bottom of the paper. Remember that the link words that connect the concepts can give you good hints. Can you figure out where the concepts go? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* gray ovals are blank. Here is our map. (Pass out copies of student map.) Can you read it and figure out where the missing concepts go? Here is a pencil for you to write the concepts in the ovals. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOTHERMAL ENERGY



DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE FROM THE LIST BELOW.

**ELECTRICITY
HEAT
FACTORIES**

**WASTE
MAGMA
STEAM**

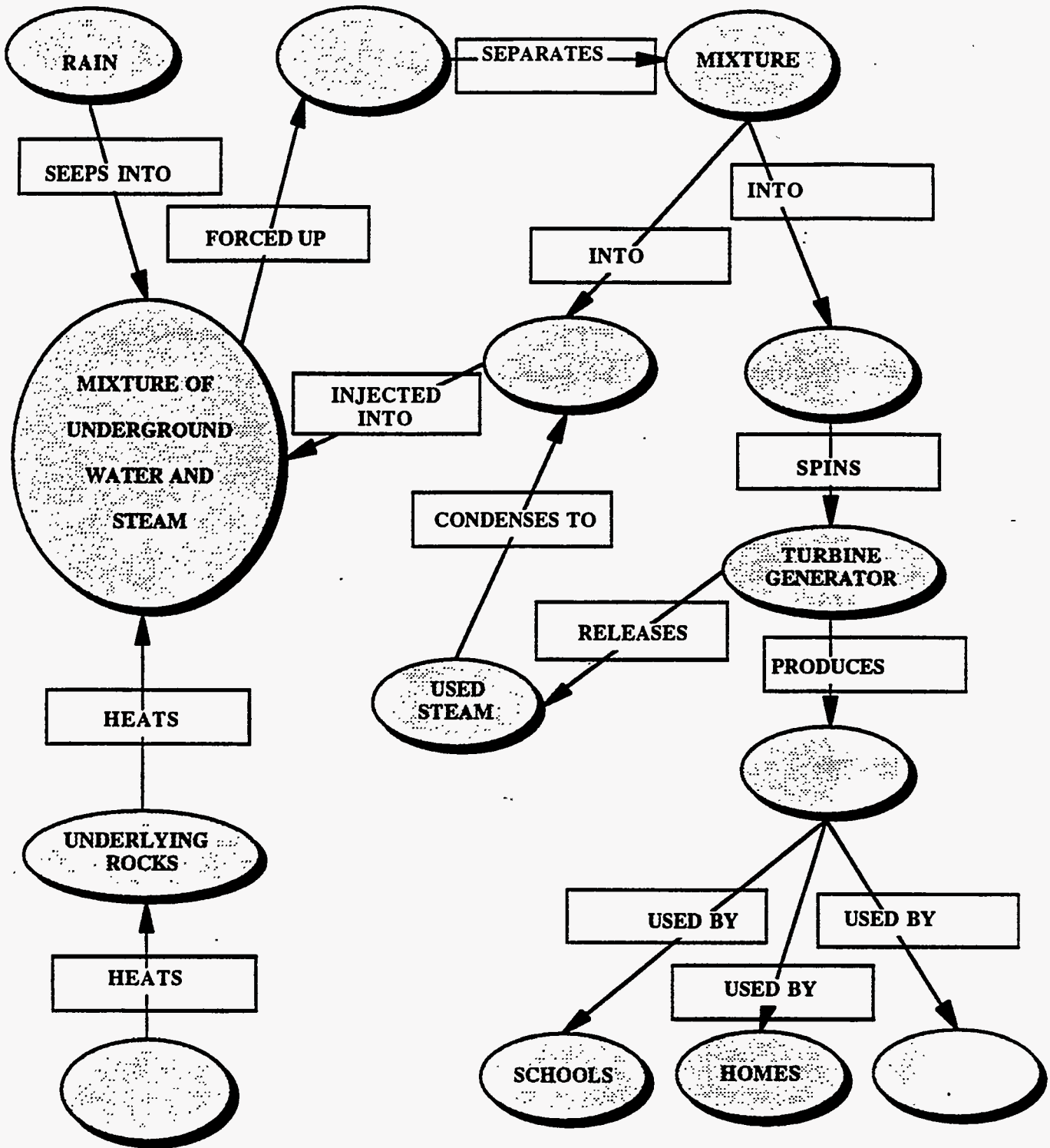
**WATER
SUN
PIPE**

Leader Directions: Some nodes, fill-in, with distracters

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) The missing concepts are listed at the bottom of the paper, along with an extra one just to see if you can spot it. Remember that the link words that connect the concepts can give you good hints. Can you figure out where the concepts go? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* gray ovals are blank. Here is our map. (Pass out copies of student map.) Can you read it and figure out where the missing concepts go? Remember, some of them will be extras! Here is a pencil for you to write the missing concepts in the ovals. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOTHERMAL ENERGY



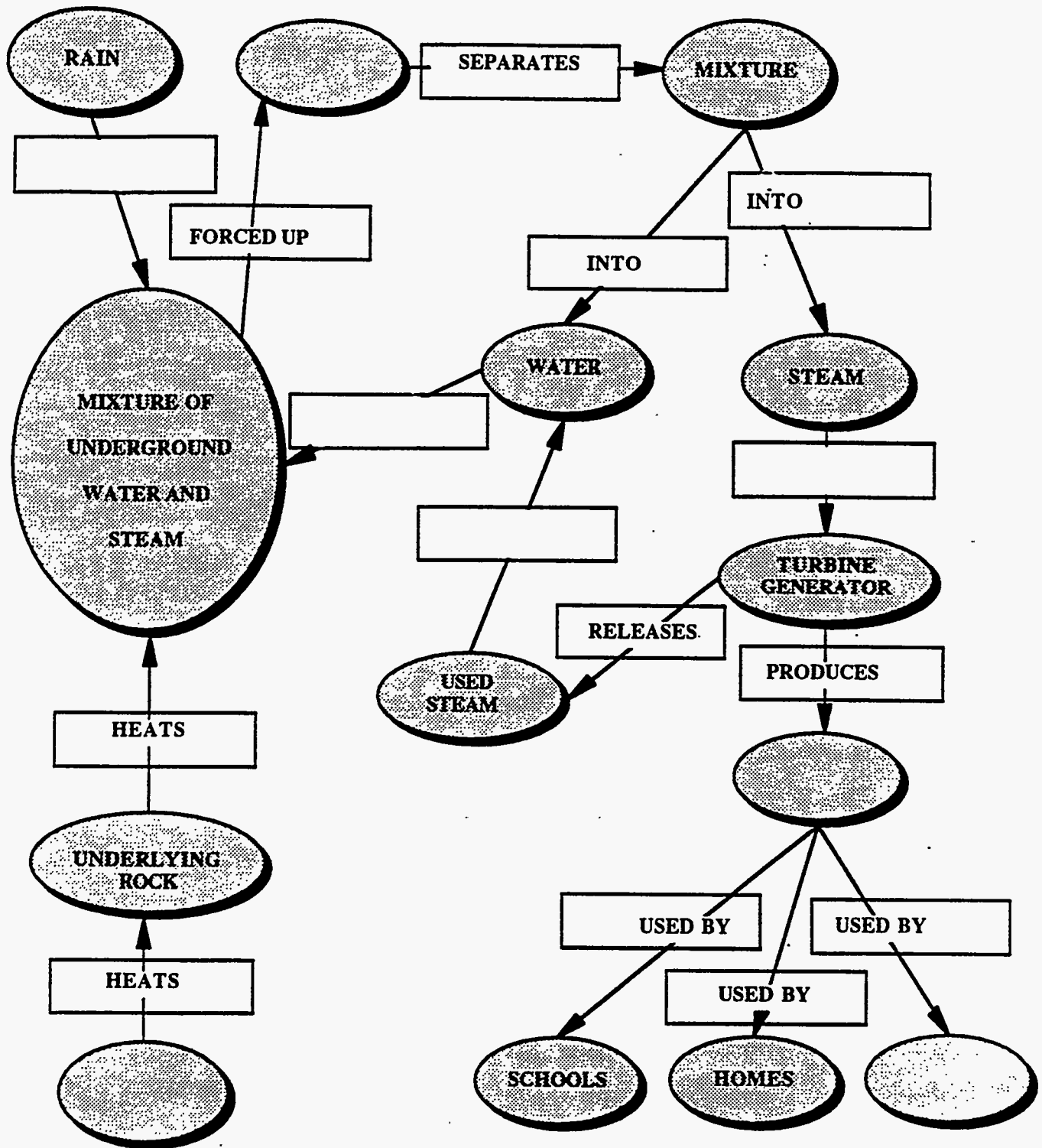
DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE THAT YOU THINK BELONGS THERE.

Leader Directions: Some nodes, generate

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) Remember that the link words that connect the ovals can give you good hints. Can you think of some concepts to put in? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* gray ovals are blank. Here is our map. (Pass out copies of student map.) Can you read it and figure out what would go in the blank ovals? Here is a pencil for you to write in the missing concepts. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOHERMAL ENERGY



DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE FROM THE LIST BELOW.

CONDENSES TO
ELECTRICITY
INJECTED INTO

SPINS
FACTORIES
MAGMA

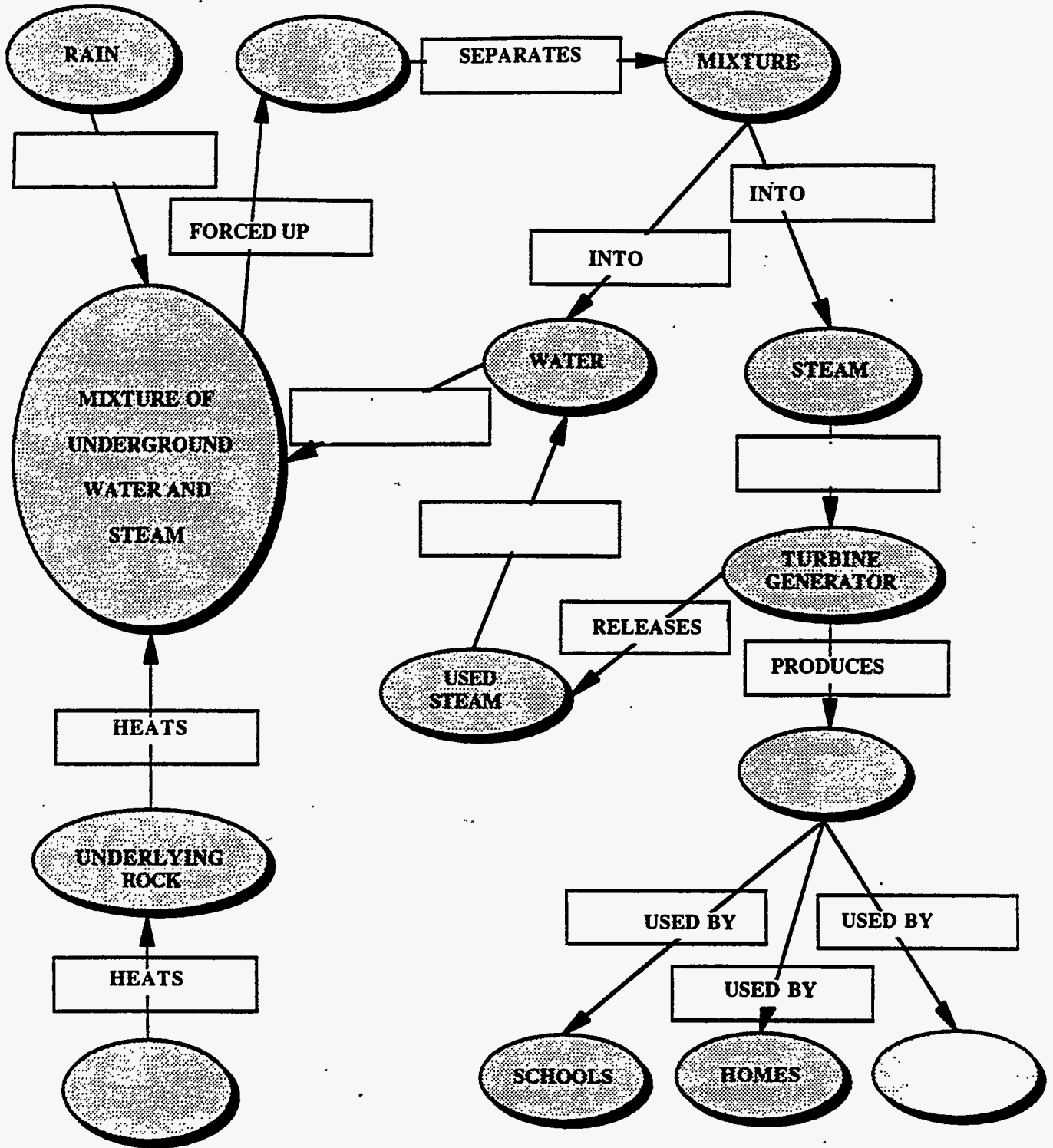
SEEPS INTO
PIPE

Leader Directions: Some nodes and links, fill-in

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the links out of the white rectangles and some of the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) The missing words are listed at the bottom of the page. Can you figure out which concepts and link words would make sense to put in the blanks? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* white rectangles ^(for links) and gray ovals ^(for concepts) are blank too. Here is our map. (Pass out copies of student map.) Can you read it and figure out what link words and concepts to put in to make the map make sense? Here is a pencil for you to write the missing concepts and link words. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOTHERMAL ENERGY



DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE FROM THE LIST BELOW.

SUN
SEEPS INTO
ELECTRICITY
INJECTED INTO

CONDENSES TO
WASTE
FACTORIES
MAGMA

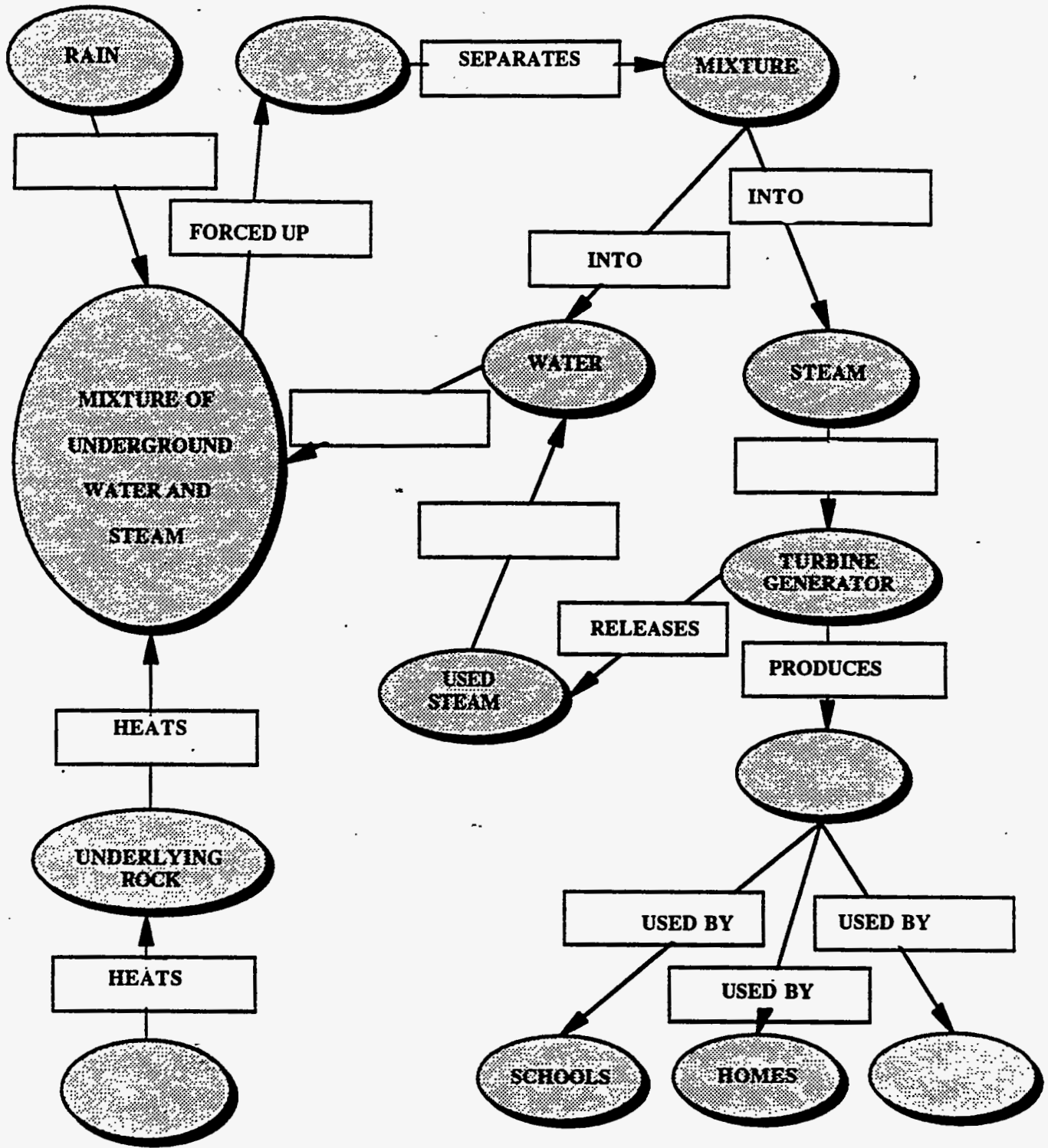
SPINS
DISSOLVES
PIPE
EVAPORATES

Leader Directions: Some nodes and links, fill-in, distracters

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the links out of the white rectangles and some of the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) The missing words are listed at the bottom of the page, along with ~~an~~ extra word^{AD} to see if you can spot ~~it~~^{them}! Can you figure out which concepts and link words would make sense to put in the blanks? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* white rectangles and gray ovals are blank too. Here is our map. (Pass out copies of student map.) Can you read it and figure out what link words and concepts to put in to make the map make sense? Remember, some of the words in the list are extras! Here is a pencil for you to write the missing concepts and link words. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOHERMAL ENERGY



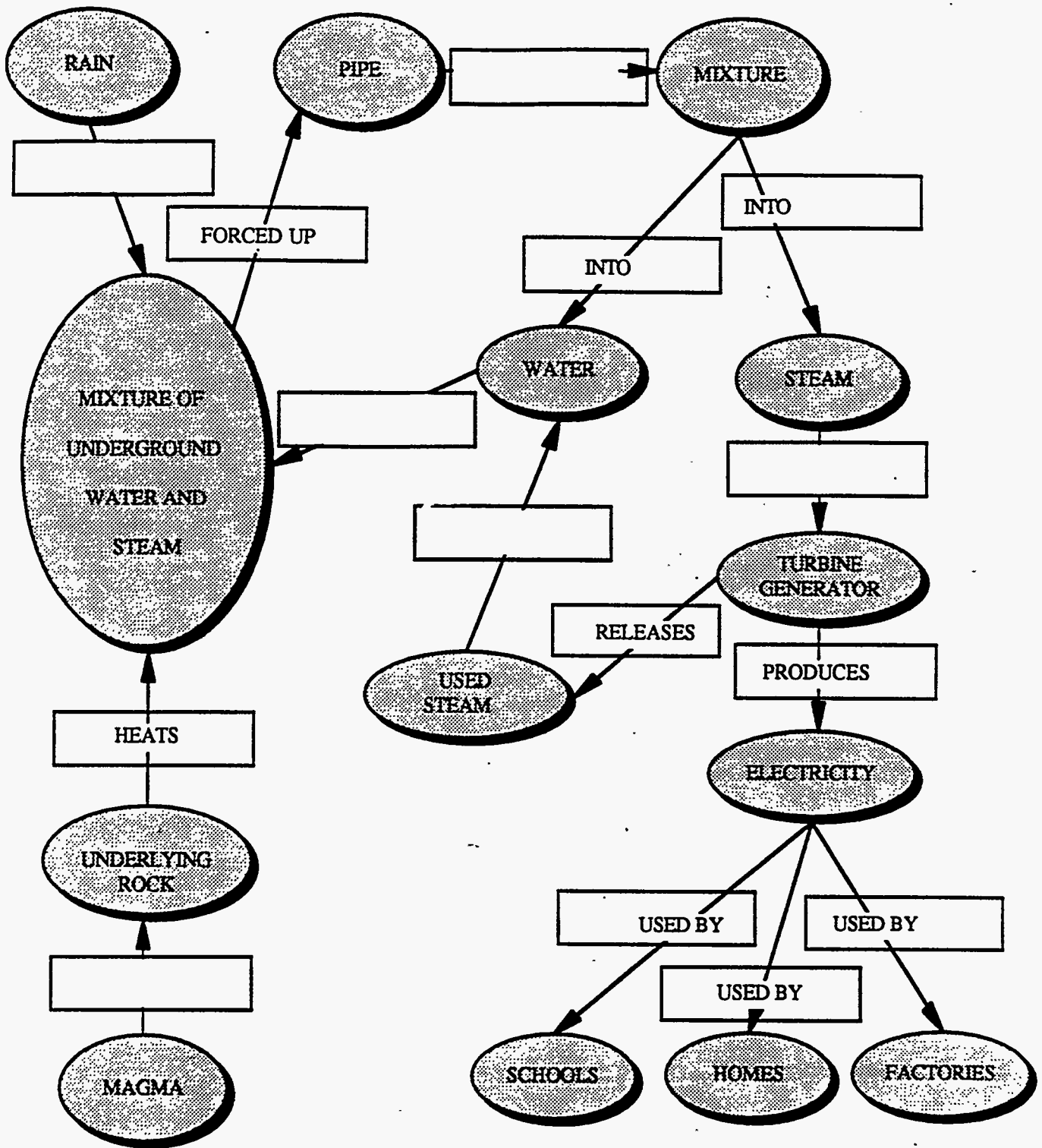
DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE THAT YOU THINK BELONGS THERE.

Leader Directions: Some nodes and links, generate

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the links out of the white rectangles and some of the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) Can you figure out what concepts and link words would make sense to put in the blanks? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* white rectangles and gray ovals are blank too. Here is our map. (Pass out copies of student map.) Can you read it and figure out what link words and concepts to put in to make the map make sense? Here is a pencil for you to write the missing concepts and link words. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOTHERMAL ENERGY



DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE FROM THE LIST BELOW.

INJECTED INTO
SEPARATES
HEATS

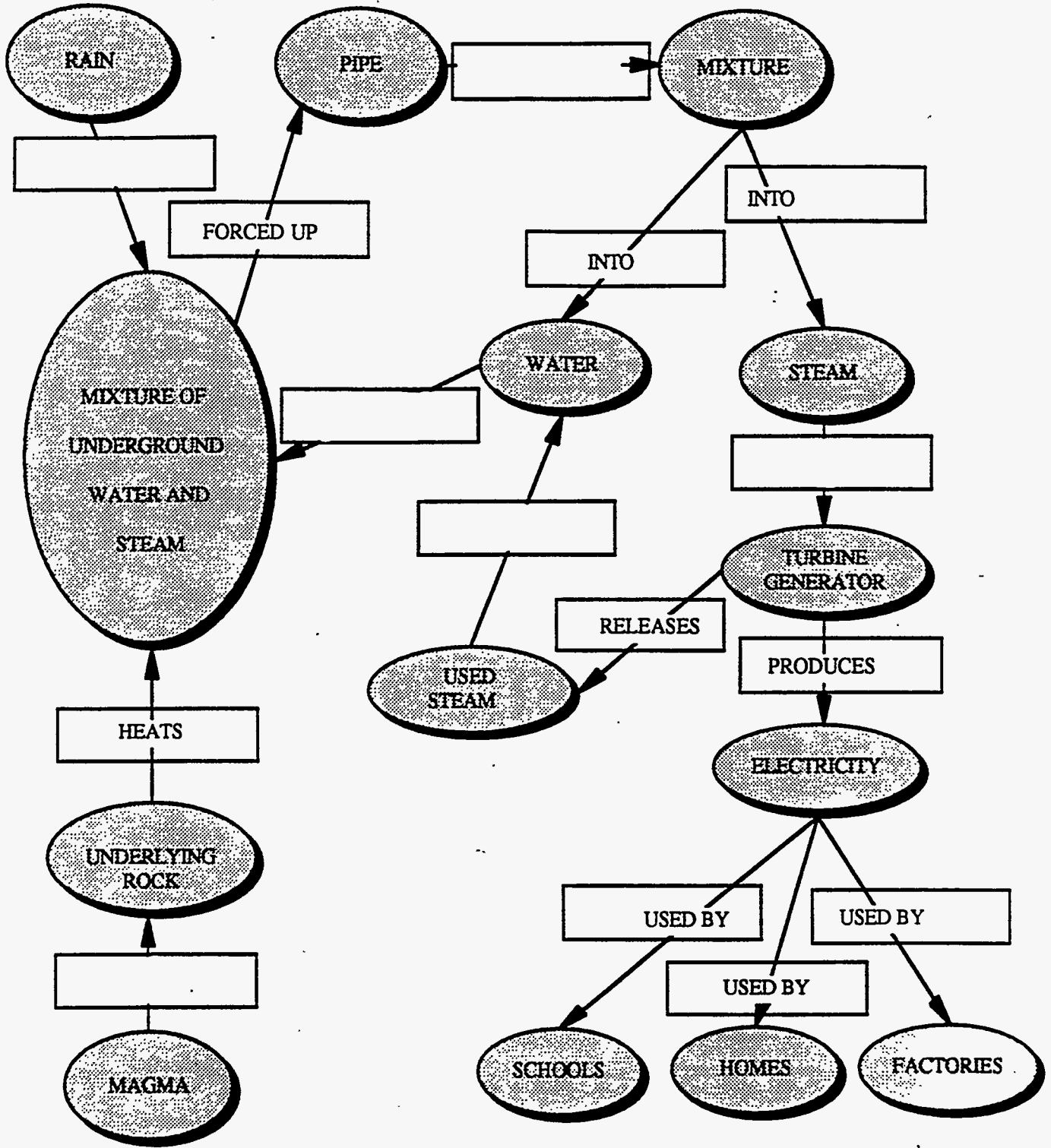
SPINS
CONDENSES TO
SEEPS INTO

Leader Directions: Some links, fill-in

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the linking words out of the white rectangles. (Show students the example concept map from manila envelope.) The missing link words are listed at the bottom of the paper. Remember that the concepts surrounding the rectangles can give you good hints. Can you figure out where the linking words go? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* white rectangles are blank. Here is our map. (Pass out copies of student map.) Can you read it and figure out which links would go in the blank rectangles? Here is a pencil for you to write in the missing link words. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOHERMAL ENERGY



DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE FROM THE LIST BELOW.

INJECTED INTO
COMES FROM
DISSOLVES

EVAPORATES
SEPARATES
HEATS

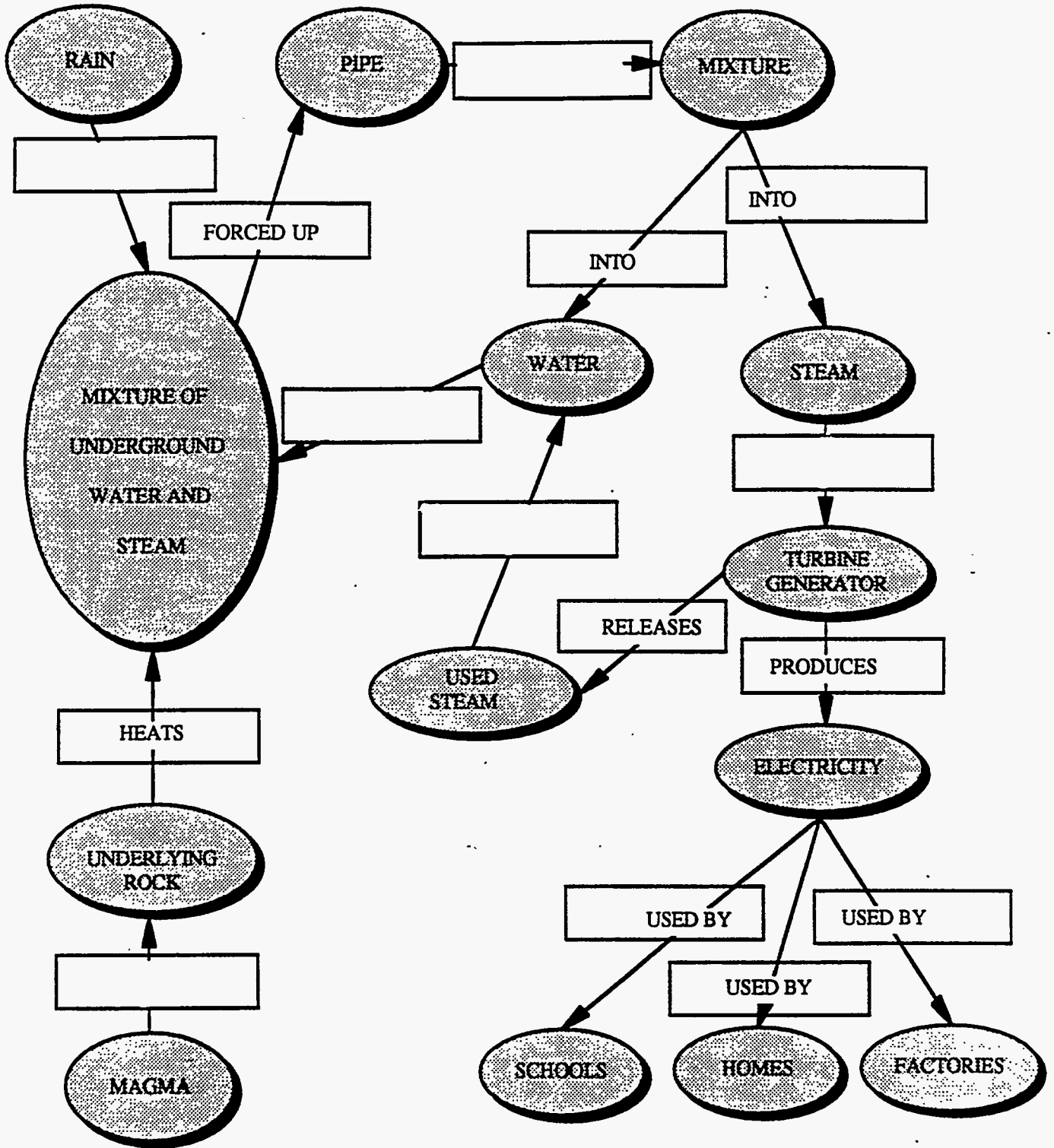
SPINS
CONDENSES TO
SEEPS INTO

Leader Directions: Some links, fill-in with distractors

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the linking words out of the white rectangles. (Show students the example concept map from manila envelope.) The missing link words are listed at the bottom of the paper, along with an extra one just to see if you can spot it. Remember that the concepts surrounding the rectangles can give you good hints. Can you figure out where the linking words go? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* white rectangles are blank. Here is our map. (Pass out copies of student map.) Can you read it and figure out which links would go in the blank rectangles? Remember, some of them will be extras! Here is a pencil for you to write in the missing link words. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOHERMAL ENERGY



DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE THAT YOU THINK BELONGS THERE.

Leader Directions: Some links, generate

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the linking words out of the white rectangles. (Show students the example concept map from manila envelope.) Remember that the concepts surrounding the rectangles can give you good hints. Can you think of some linking words to put in? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* white rectangles are blank. Here is our map. (Pass out copies of student map.) Can you read it and figure out what would go in the blank rectangles? Here is a pencil for you to write in the missing link words. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOHERMAL ENERGY

DIRECTIONS: Use the words and phrases in the envelope to make a concept map of what you know about geothermal energy.

Leader Directions: Generate structure, movable words

We wanted to make a puzzle out of our concept map about renewable energy resources, so we made concept words that you can move around on the page. (Show students the example concept map and the blue concepts in small envelope.) Can you help me draw our own map with these words? Remember, we have to connect the concepts with arrows and linking words. When we are sure where we want the concepts to go, let's tape them down. (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But all that is here is a blank page with an envelope with lots of movable blue concepts. (Pass out copies of student map.) Can you draw your own concept map using these words? Remember the arrows and see if you can make up some linking words too. When you are sure where you want the concepts on the paper, use this tape to tape them down. Here is a pencil for you. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOTHERMAL ENERGY

DIRECTIONS: Use the words and phrases below to make a concept map of what you know about geothermal energy.

ELECTRICITY
WATER
SCHOOLS
TURBINE GENERATOR
UNDERGROUND WATER AND STEAM

MAGMA
STEAM
RAIN
PIPE
HOMES

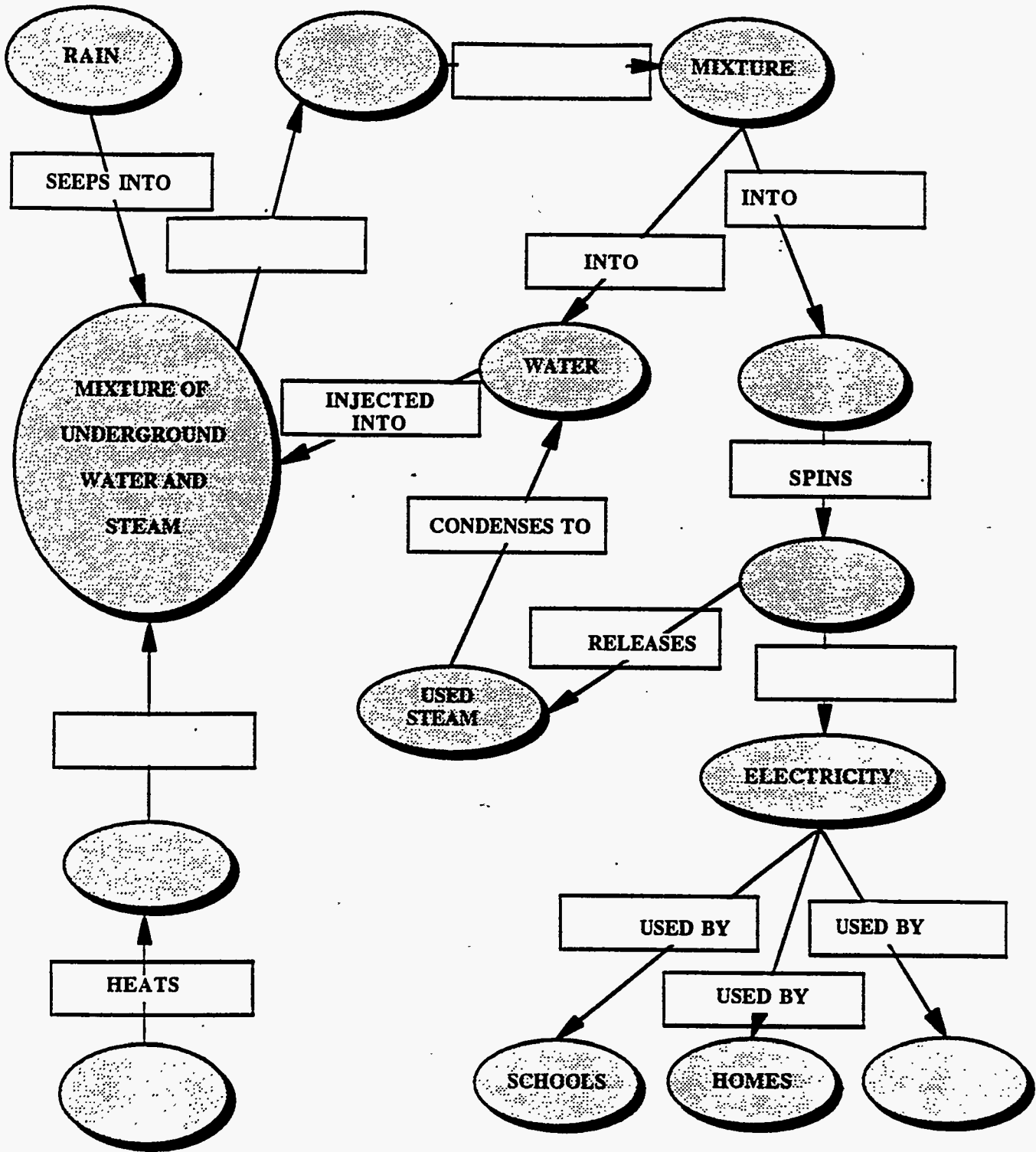
UNDERLYING ROCK
FACTORIES
USED STEAM
MIXTURE

Leader Directions: Generate structure

We wanted to make a puzzle out of our concept map about renewable energy resources, so we just listed the concept words at the bottom of the page. (Show students the example concept map from manila envelope.) Can you help me draw our own map with these words? Remember, we have to connect the concepts with arrows and linking words. (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But all that is here is a list of concept words at the bottom!. Here is our map. (Pass out copies of student map.) Can you draw your own concept map using these words? Remember the arrows and see if you can make up some linking words too. Here is a pencil for you. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOHERMAL ENERGY



DIRECTIONS: Fill in each blank with a word or phrase from the list below.

SEPARATES
TURBINE GENERATOR
MAGMA

PIPE
UNDERLYING ROCK
FORCED UP
FACTORIES

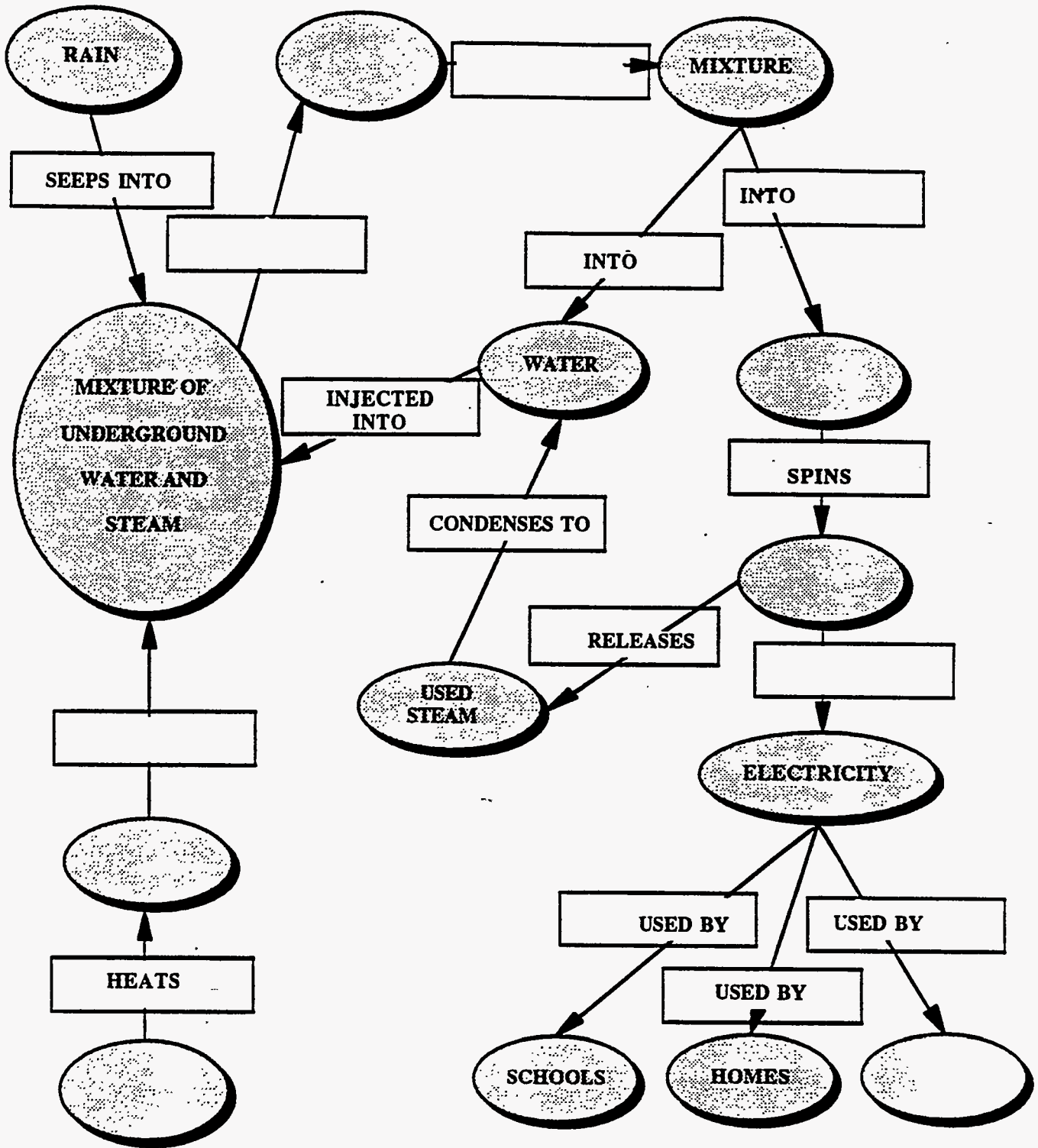
PRODUCES
STEAM
HEATS

Leader Directions: Experimental, fill-in,

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the links out of the white rectangles and some of the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) The missing words are listed at the bottom of the page. Can you figure out which concepts and link words would make sense to put in the blanks? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* white rectangles and gray ovals are blank too. Here is our map. (Pass out copies of student map.) Can you read it and figure out what link words and concepts to put in to make the map make sense? Here is a pencil for you to write the missing concepts and link words. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOTHERMAL ENERGY



DIRECTIONS: Fill in each blank with a word or phrase from the list below.

SEPARATES
TURBINE GENERATOR
MAGMA
WASTE

EVAPORATES
PIPE
UNDERLYING ROCK
FORCED UP
FACTORIES

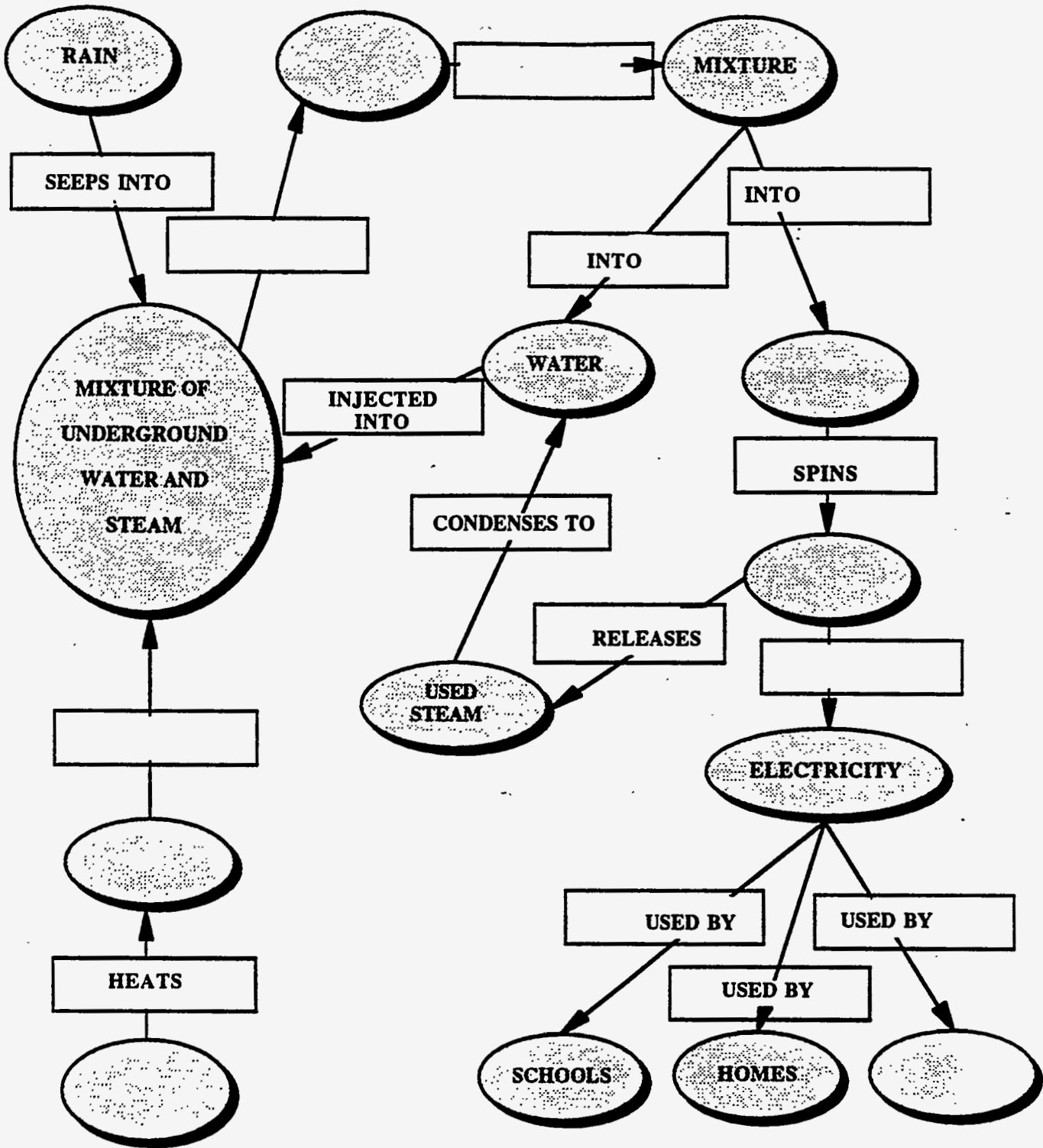
PRODUCES
SUN
STEAM
HEATS

Leader Directions: Experimental, fill-in, distracters

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the links out of the white rectangles and some of the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) The missing words are listed at the bottom of the page, along with ~~an~~ extra word to see if you can spot ^{it}! Can you figure out which concepts and link words would make sense to put in the blanks? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* white rectangles and gray ovals are blank too. Here is our map. (Pass out copies of student map.) Can you read it and figure out what link words and concepts to put in to make the map make sense? Remember, some of the words in the list are extras! Here is a pencil for you to write the missing concepts and link words. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOTHERMAL ENERGY



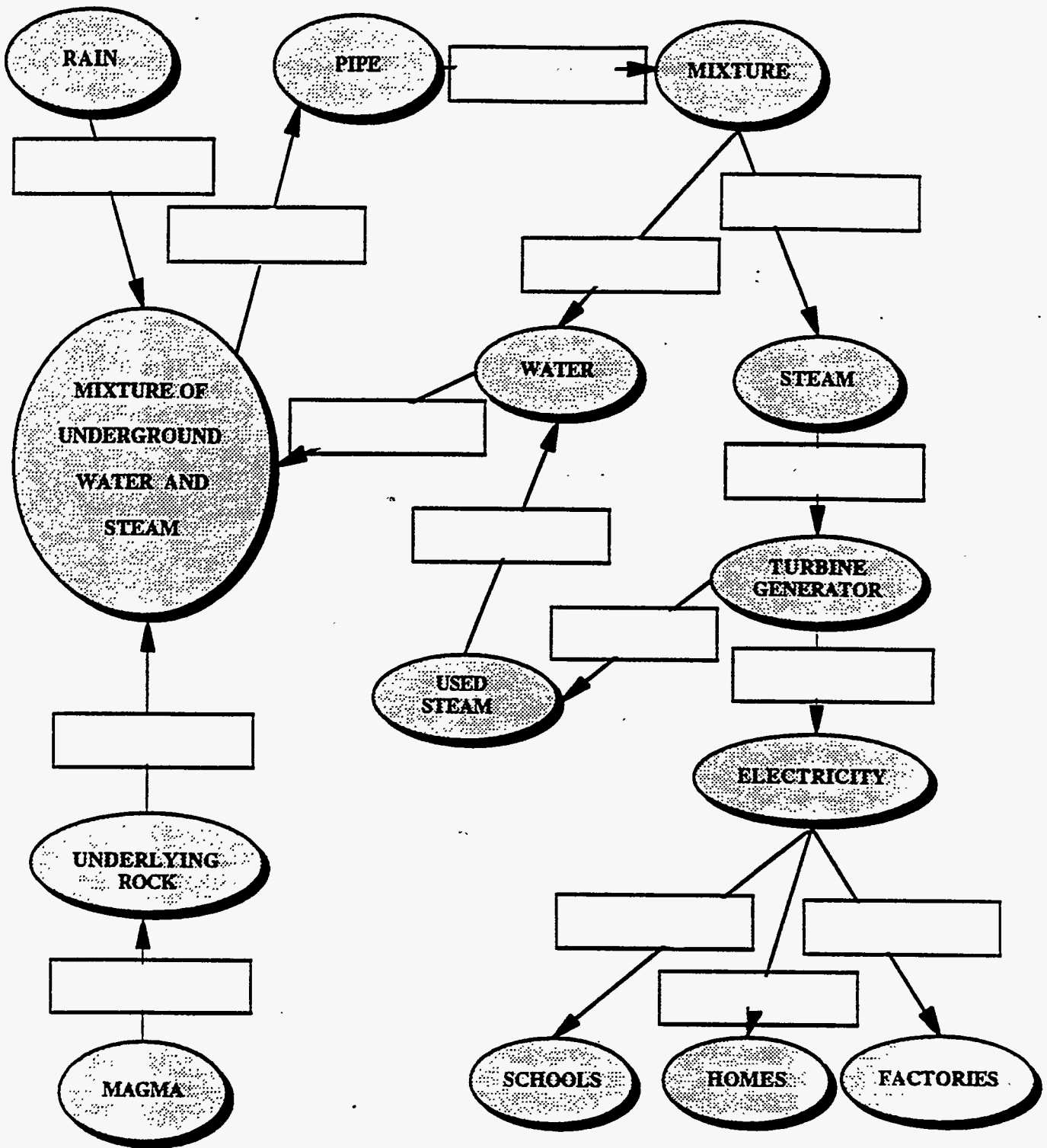
DIRECTIONS: Fill in each blank with a word or phrase that you think belongs there.

Leader Directions: Experimental, generate

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took some of the links out of the white rectangles and some of the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) Can you figure out which concepts and link words would make sense to put in the blanks? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* white rectangles and gray ovals are blank too. Here is our map. (Pass out copies of student map.) Can you read it and figure out what link words and concepts to put in to make the map make sense? Here is a pencil for you to write the missing concepts and link words. (Pass out pencils.) First, please write your full name and the period.# at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOTHERMAL ENERGY



DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE FROM THE LIST BELOW.

INJECTED INTO
SPINS
RELEASES

FORCED UP
USED BY
HEATS
INTO

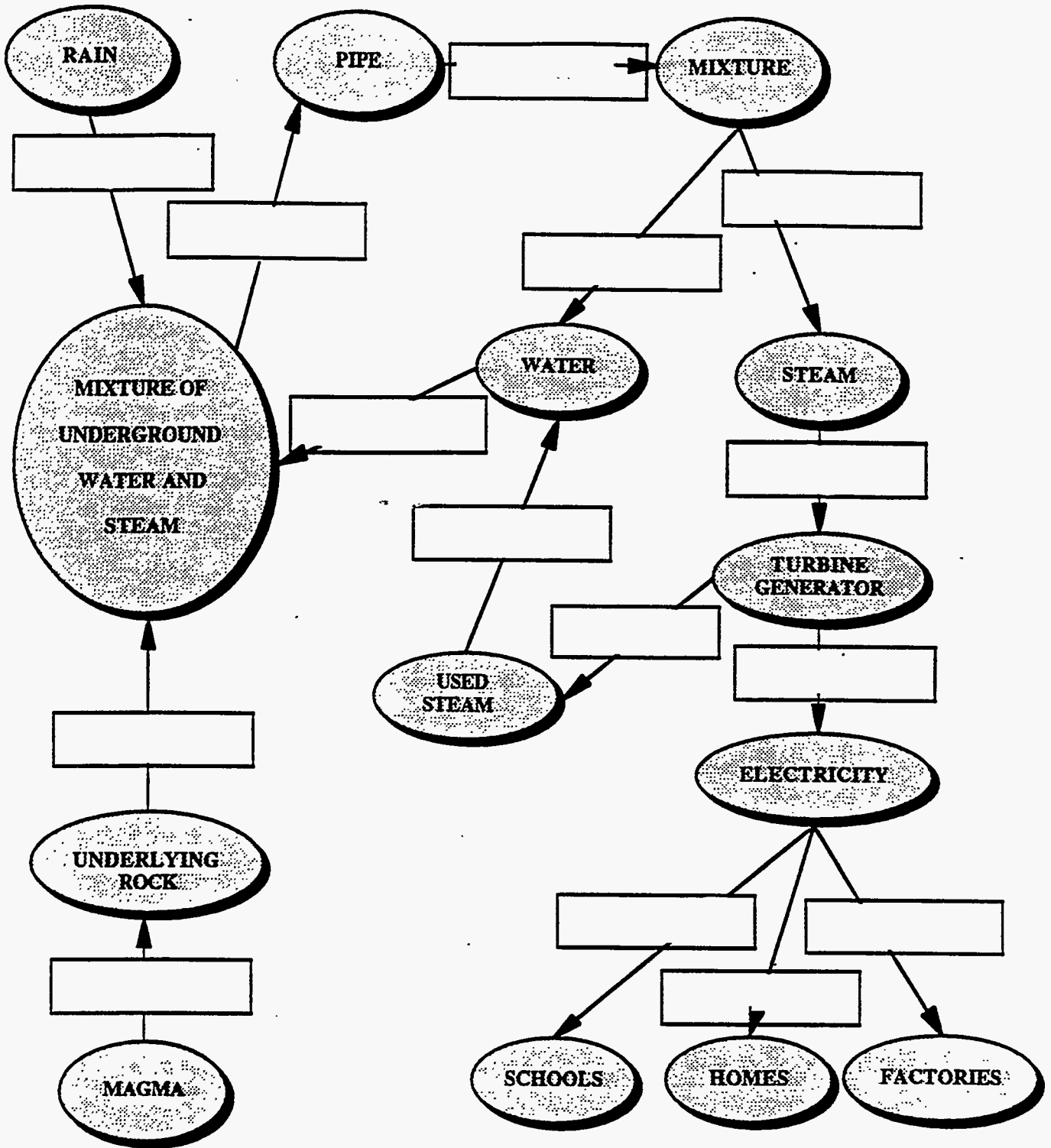
SEPARATES
CONDENSES TO
SEEPS INTO
PRODUCES

Leader Directions: All links, fill-in

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took the links out of the white rectangles on our map. (Show students the example concept map from manila envelope.) The missing linking words are listed at the bottom of the paper. Remember that the concepts connected to the blanks can give you good hints. Can you figure out where the link words go? You can use the link words more than once. (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But *these* white rectangles are blank too. Here is our map. (Pass out copies of student map.) Can you read it and figure out where the missing link words go? Remember that you can use the link words more than once. Here is a pencil for you to write the missing link words in the rectangles. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEPHERMAL ENERGY



DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE FROM THE LIST BELOW.

INJECTED INTO
SPINS
EVAPORATES
COMES FROM
RELEASES

FORCED UP
DISSOLVES
USED BY
HEATS
INTO

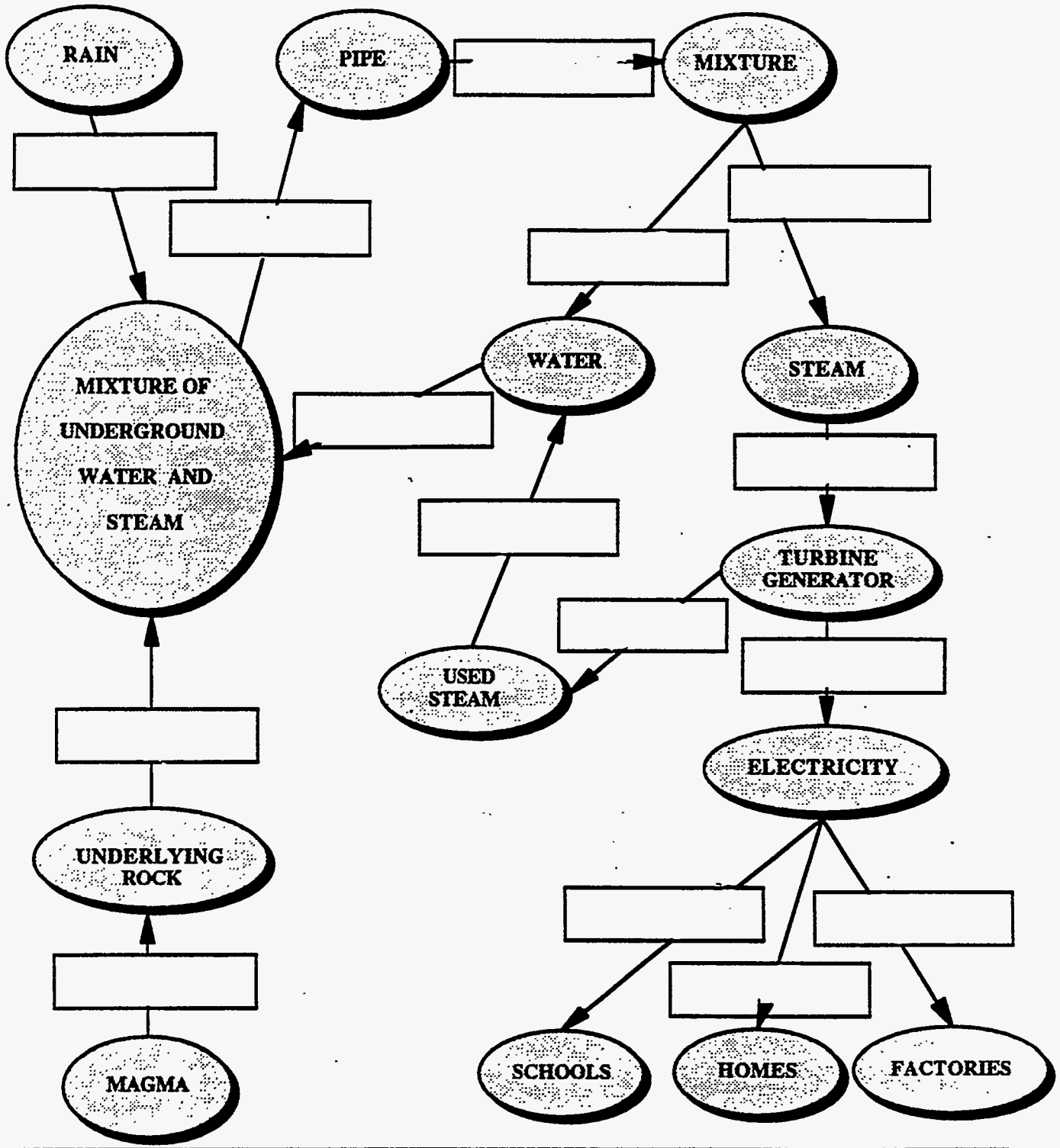
SEPARATES
CONDENSES TO
SEEPS INTO
PRODUCES

Leader Directions: All links, fill-in, with distracters

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took the links out of the white rectangles on our map. (Show students the example concept map from manila envelope.) The missing linking words are listed at the bottom of the paper, along with an extra one just to see if you can spot it. Remember that the concepts connected to the blanks can give you good hints. Can you figure out where the link words go? You can use the link words more than once. (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But *these* white rectangles are blank too.. Here is our map. (Pass out copies of student map.) Can you read it and figure out where the missing link words go? Remember, some of them will be extras! And you can use the link words more than once. Here is a pencil for you to write the missing link words in the rectangles. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOHERMAL ENERGY

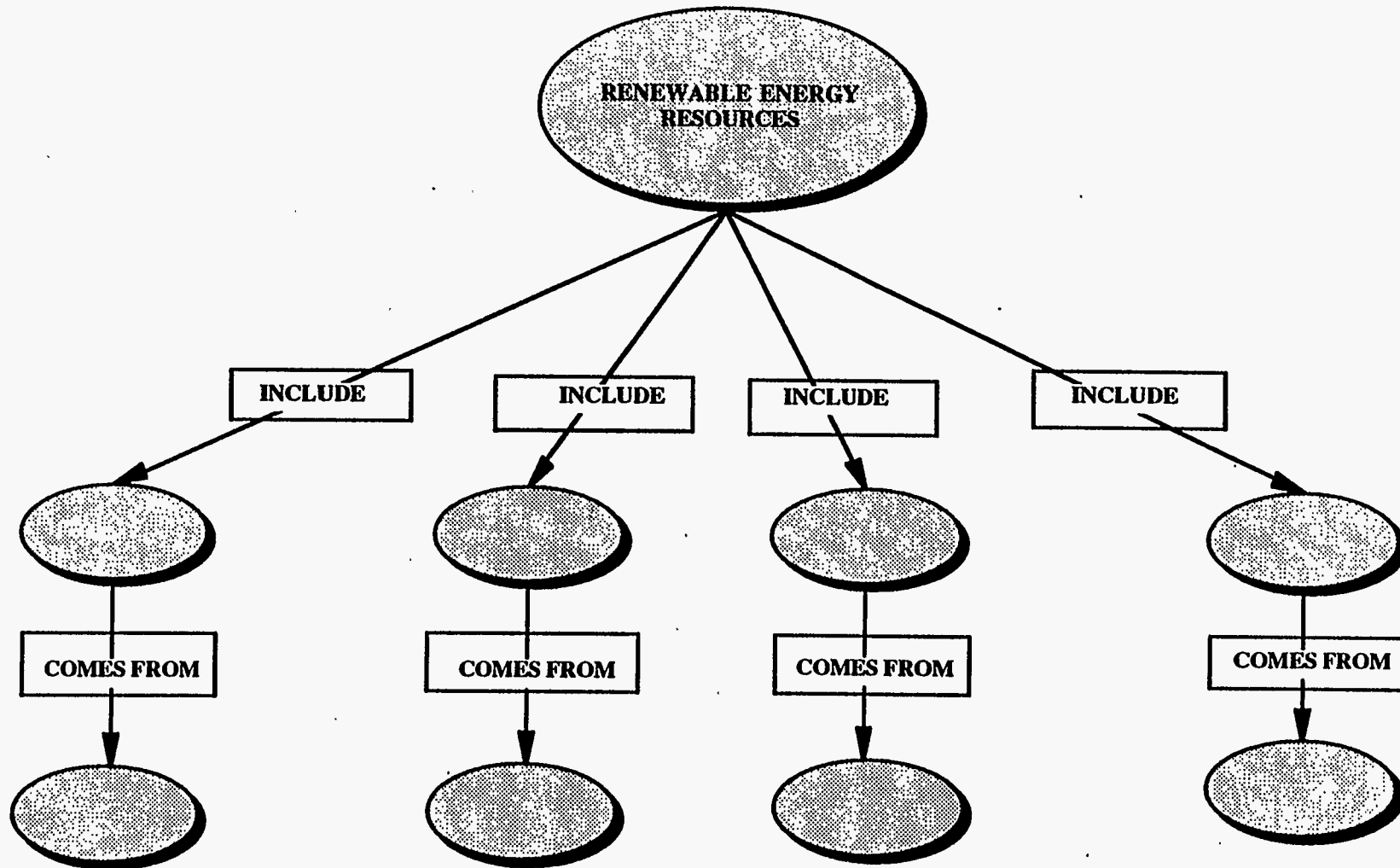


DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE THAT YOU THINK BELONGS THERE.

Leader Directions: All links, gen

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took the links out of the white rectangles on our map. (Show students the example concept map from manila envelope.) Remember that the concepts connected to the blanks can give you good hints. Can you figure out what link words to put in these rectangles? You can use the link words more than once. (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But *these* white rectangles are blank too. Here is our map. (Pass out copies of student map.) Can you read it and figure out what link words to put in to make the map make sense? Remember that you can use the link words more than once. Here is a pencil for you to write the missing link words in the rectangles. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.



DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE FROM THE LIST BELOW.

WIND
MOVING WATER
INTERNAL HEAT OF EARTH
SUN

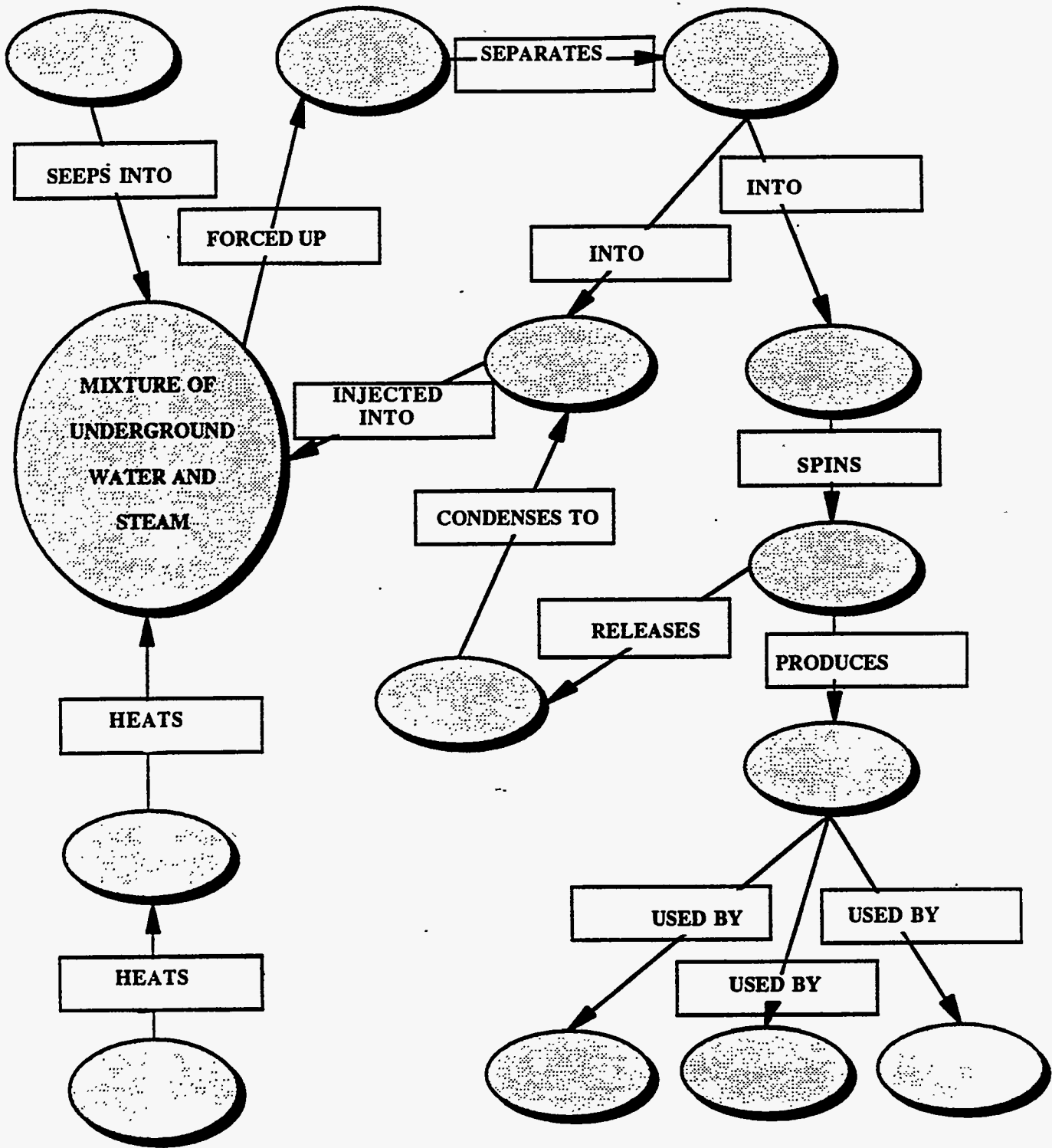
GEOHERMAL
UNEQUAL HEATING OF EARTH AND AIR
SOLAR
HYDROELECTRIC

Leader Directions: All nodes, fill-in

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) The missing concepts are listed at the bottom of the paper. Remember that the link words that connect the concepts can give you good hints. Can you figure out where the concepts go? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But *these* gray ovals are blank too. Here is our map. (Pass out copies of student map.) Can you read it and figure out where the missing concepts go? Here is a pencil for you to write the concepts in the ovals. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOTHERMAL ENERGY



DIRECTIONS: Fill in each blank with a word or phrase from the list below.

ELECTRICITY
SUN
WATER
SCHOOLS
RAIN

MAGMA
PIPE
FACTORIES
MIXTURE
WASTE
HOMES

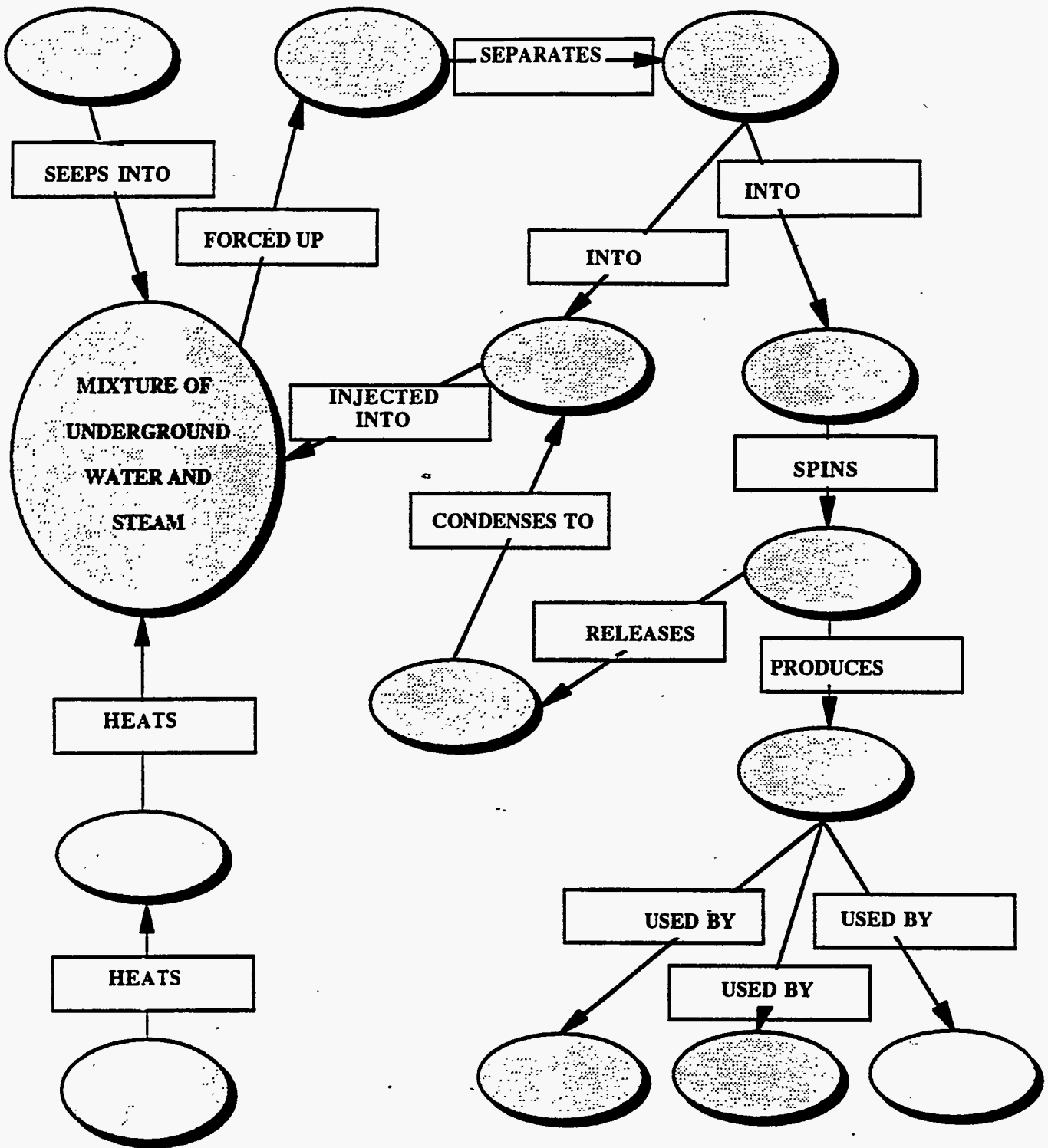
HEAT
TURBINE GENERATOR
STEAM
UNDERLYING ROCK
USED STEAM

Leader Directions: All nodes, fill-in, with distracters

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) The missing concepts are listed at the bottom of the paper, along with ^{two} an extra one ^d just to see if you can spot it. ^{them} Remember that the link words that connect the concepts can give you good hints. Can you figure out where the concepts go? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But *these* gray ovals are blank too. Here is our map. (Pass out copies of student map.) Can you read it and figure out where the missing concepts go? Remember, some of them will be extras! Here is a pencil for you to write the missing concepts in the ovals. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOHERMAL ENERGY



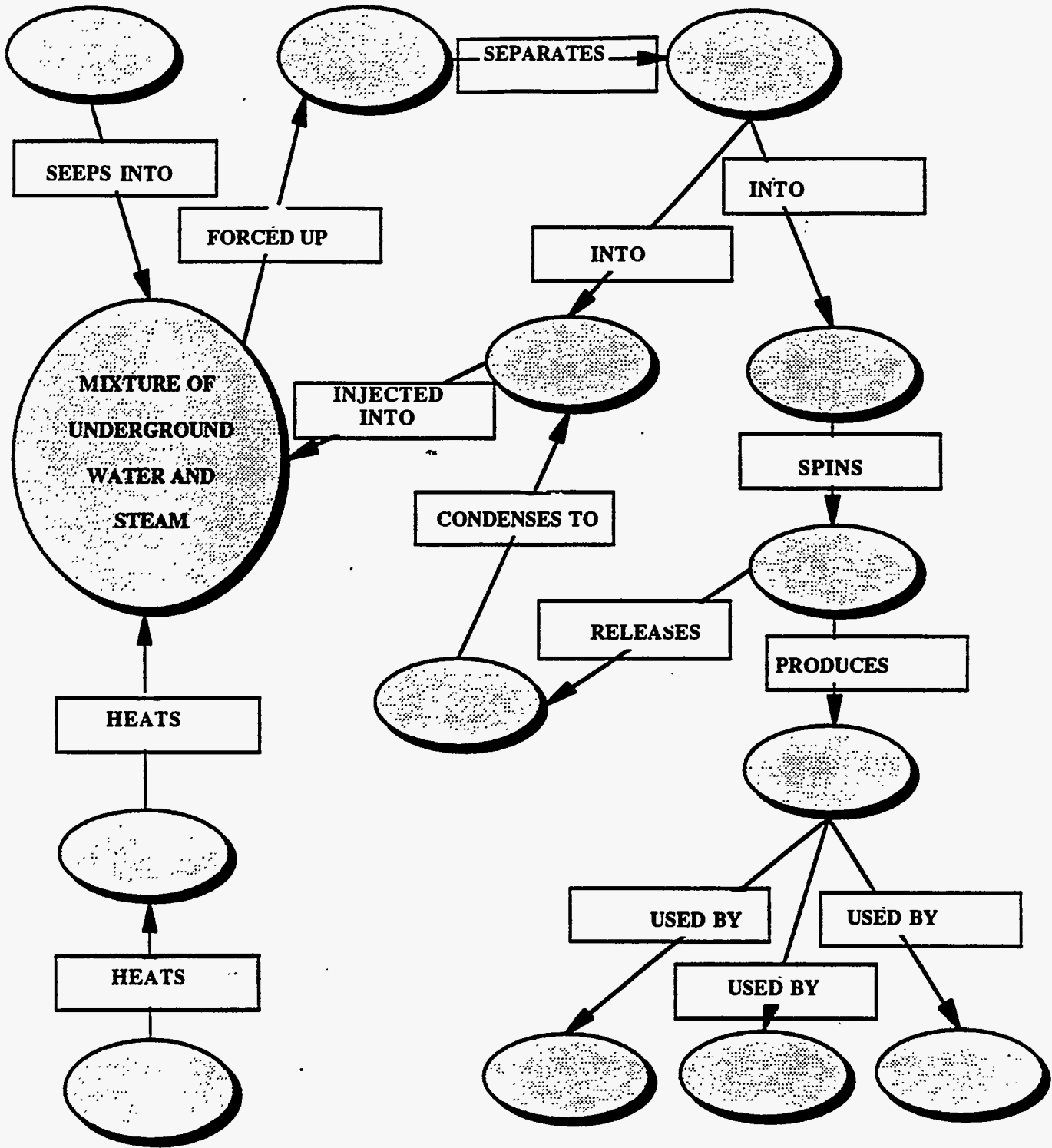
DIRECTIONS: Fill in each blank with a word or phrase that you think belongs there.

Leader Directions: All nodes, generate

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took the concepts out of the gray ovals on our map. (Show students the example concept map from manila envelope.) Remember that the link words that connect the ovals can give you good hints. Can you think of some concepts to put in? (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But *these* gray ovals are blank. Here is our map. (Pass out copies of student map.) Can you read it and figure out what would go in the blank ovals? Here is a pencil for you to write in the missing concepts. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

GEOHERMAL ENERGY



DIRECTIONS: Fill in each blank with a word or phrase from the envelope.

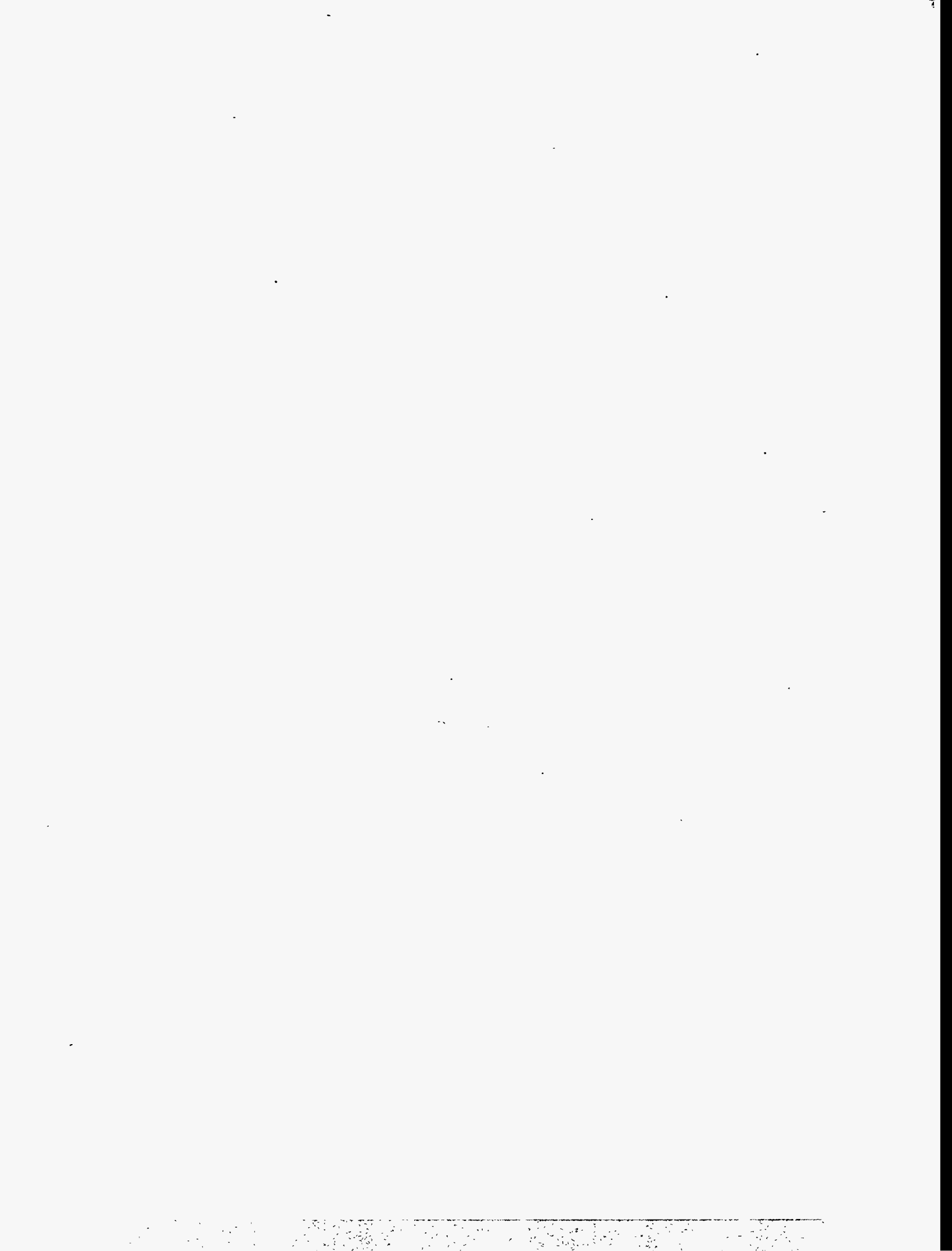
Leader Directions: All nodes, fill-in, movable

We wanted to make a puzzle out of our concept map about renewable energy resources, so we took the concepts out of the gray ovals on our map. (Show students the example concept map and the blue concepts from the small white envelope.) The missing concepts are in this envelope, separated so we can move them around on the paper. Remember that the link words that connect the concepts can give you good hints. Can you help me figure out where the concepts go? When we are sure where we want to put them we can tape them down. (Let students give ideas and reasons.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But *these* gray ovals are blank too, and the missing concepts are in the envelopes. Here is our map. (Pass out copies of student map and envelopes.) Can you read it and figure out where the missing concepts go? When you are sure where you want them to go, use the tape to tape them down. (Pass out pencils.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

Appendix II

Cuba Map Assessment Formats and Directions



Names on board and introduce. We are working with a program called TOPS (on board); TOPS stands for Teacher Opportunities to Promote Science and is sponsored by Los Alamos National Lab. We are going to the classrooms of several teachers who are part of this program. Ms. McCracken is in the program and kindly agreed to help us with our TOPS work. We are asking for your help too.

We are working on how students understand science. There are different ways to look at understanding. For example, sometimes teachers ask you questions, sometimes they give you projects to do. We have developed some new ways of looking at how students understand science that are based on concept maps. How many of you have seen CMs?

We tried out some of our ideas in another school. We used the feedback from those students to redo our maps. But some of them may be really easy, and some may be too hard. We need your help to figure this out.

We will start by showing a short video on geothermal energy:

Some sources of energy are called non-renewable - once they are used up, they are gone (e.g., gas, oil);

Some are renewable - these sources don't get used up; geothermal energy comes from renewable energy sources.

There are other sources of renewable energy; this concept map shows some of them.

Look at the whole map; 3 pieces (ovals and arrows) point to RES.

Bottom is geothermal (GE & RES in ovals cause they are ideas; arrow from GE to RES that is labeled "is a" shows how these ideas connect); it's in video so we didn't add more to map.

Both other pieces start with SUNLIGHT; ME - go to right, then left.

So, overall, map tell us that 3 sources of energy are renewable and shows how sunlight produces solar and wind energy.

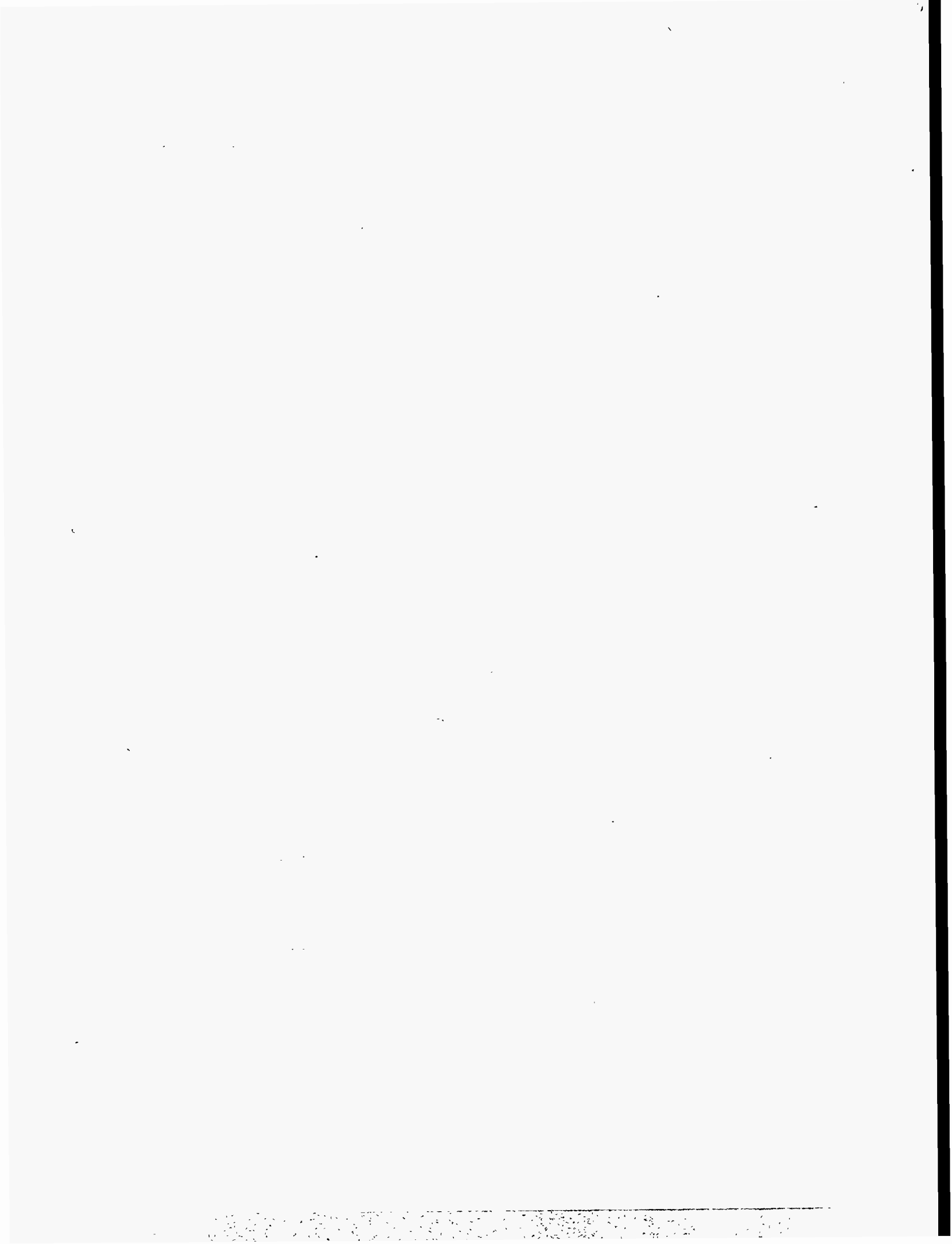
After we view video, we will put you in small groups. Then each of you will do a concept map that is like this one (only more fun, we hope) and tell us how good - or bad - they are:

First, we will ask each of you to will do your maps by yourselves;

Then your group will talk about doing the maps - how hard they were, what you liked about them, and so on.

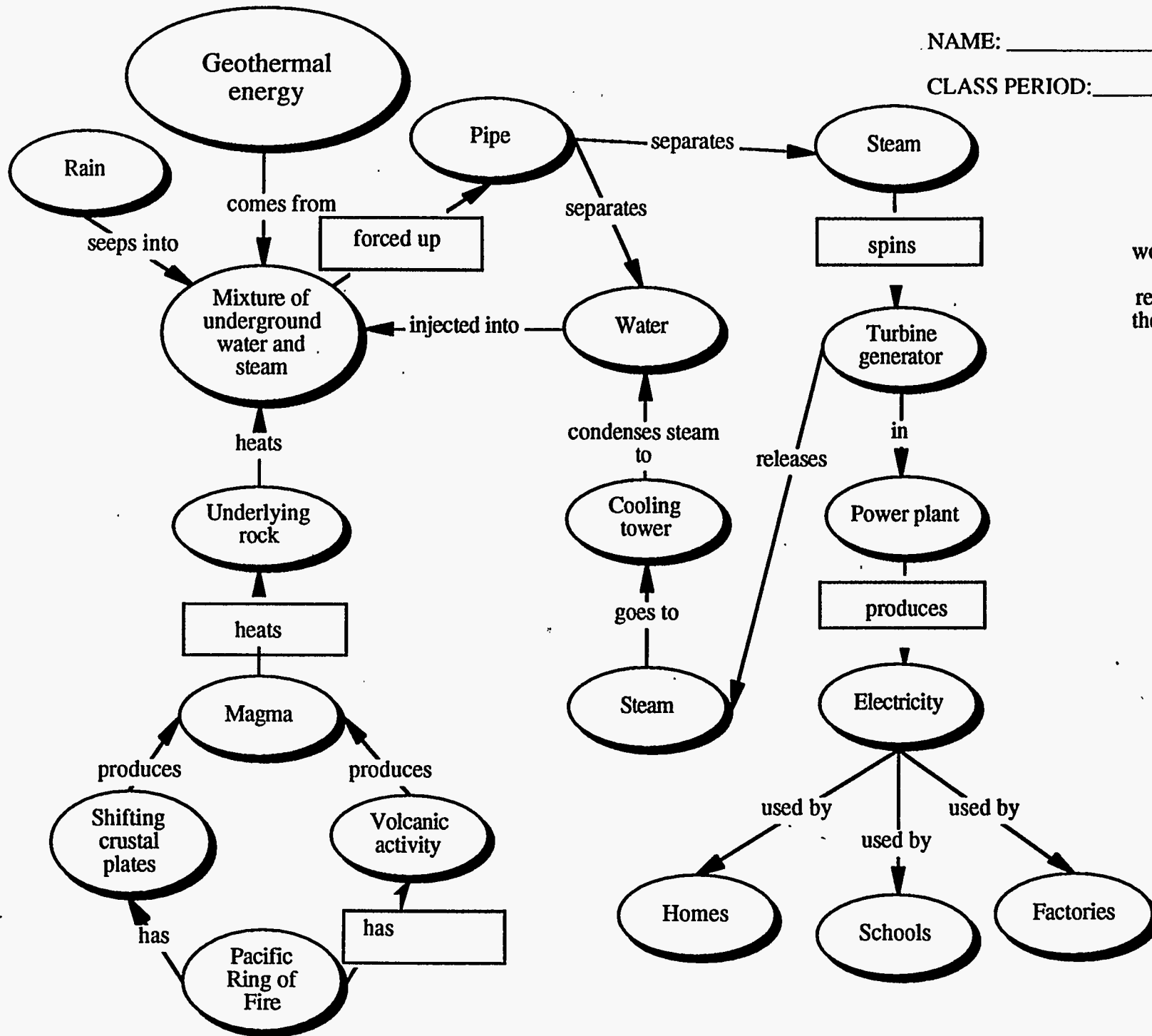
One of us will work with you in your groups as you do the maps.

Your CM will ask you about ideas that are in the video so you need to pay close attention to it. Our CMs are not tests, you won't get a grade on them. But it will help us a lot if you do your best. So let's begin by watching the video.



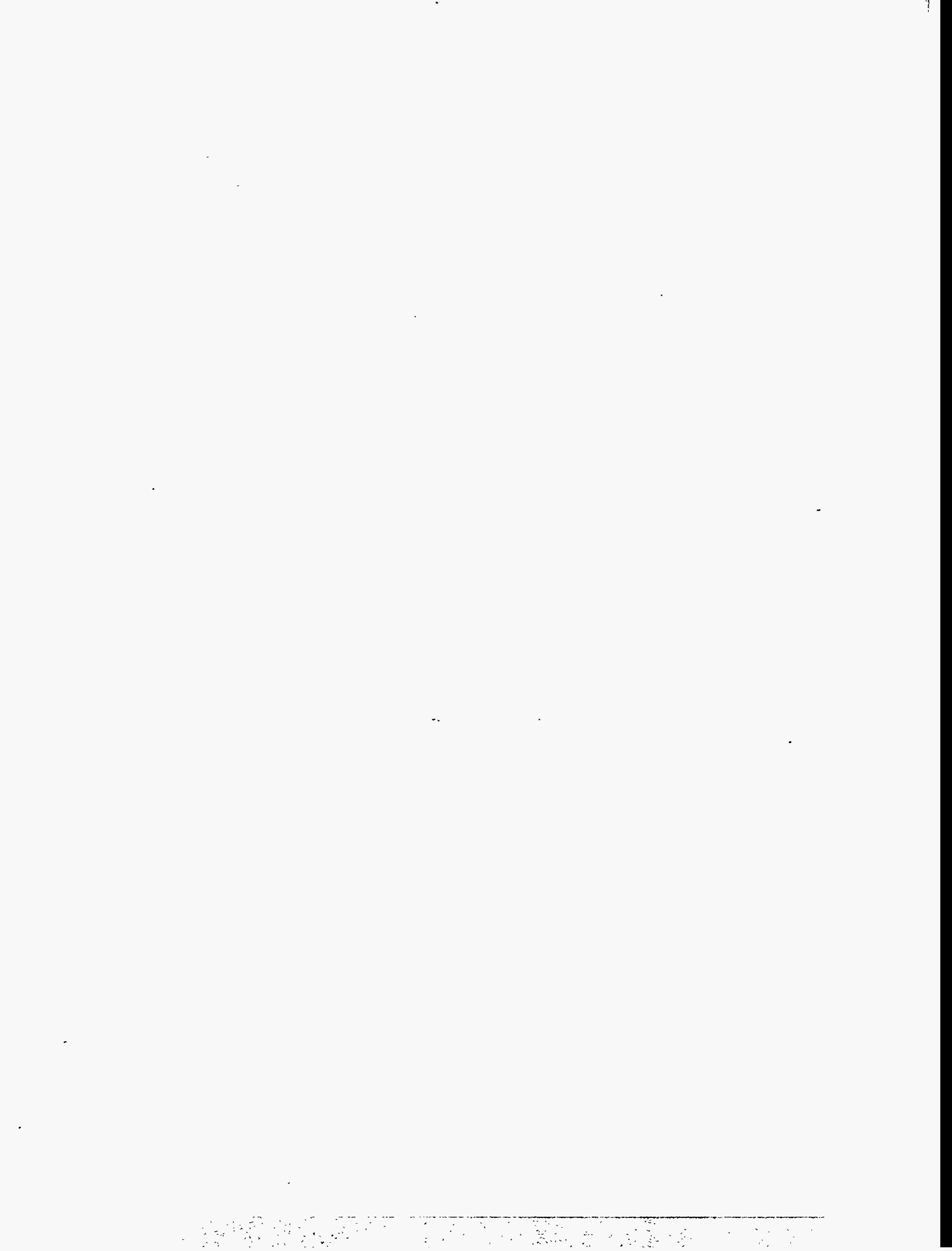
NAME: _____

CLASS PERIOD: _____



Please select from the words below to fill in each of the blank ovals and rectangles. You may use the words more than once.

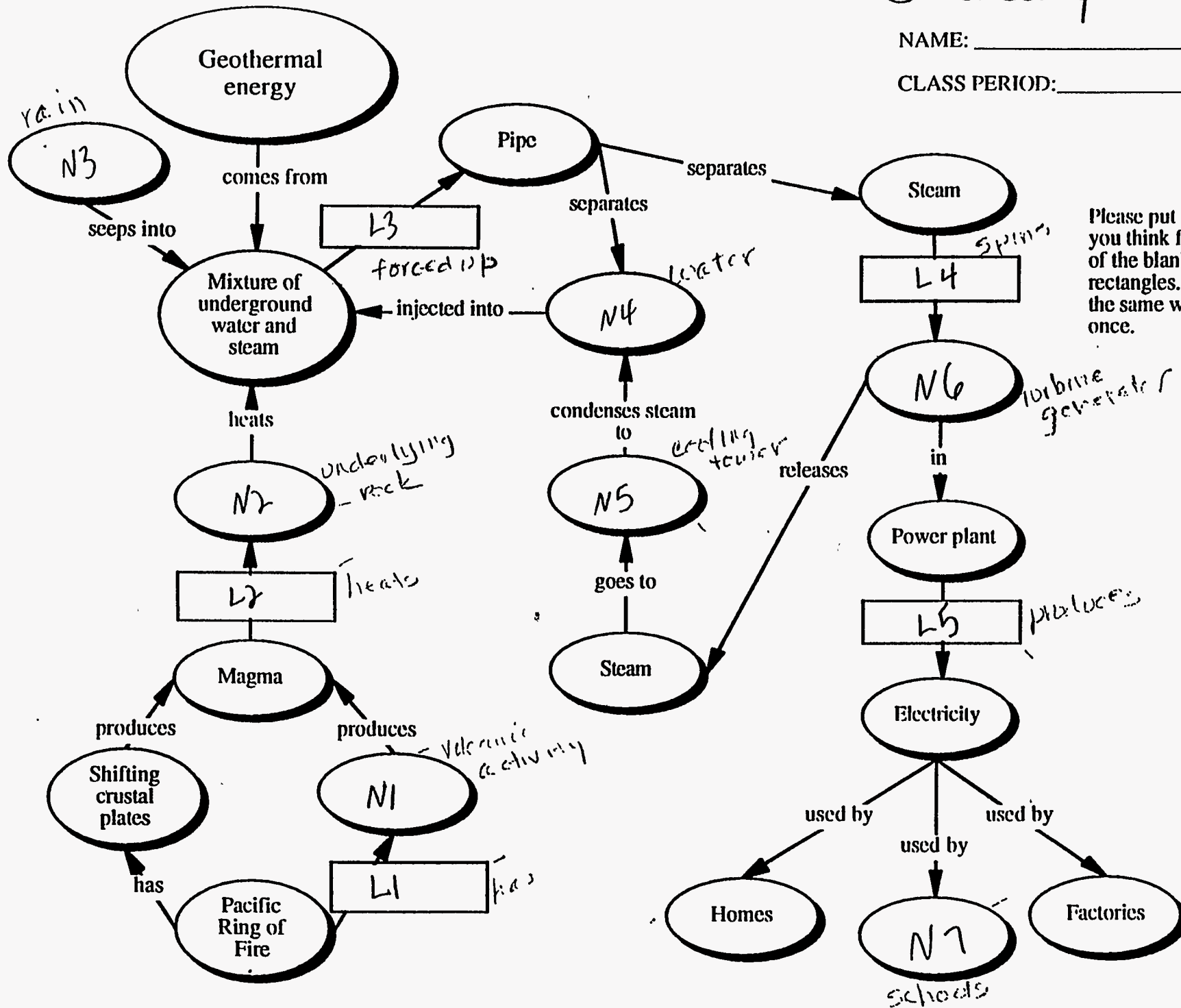
- Heats
- Forced up
- Spins
- Water
- Produces
- Turbine generator
- Underlying rock
- Schools
- Volcanic activity
- Has
- Cooling tower
- Rain



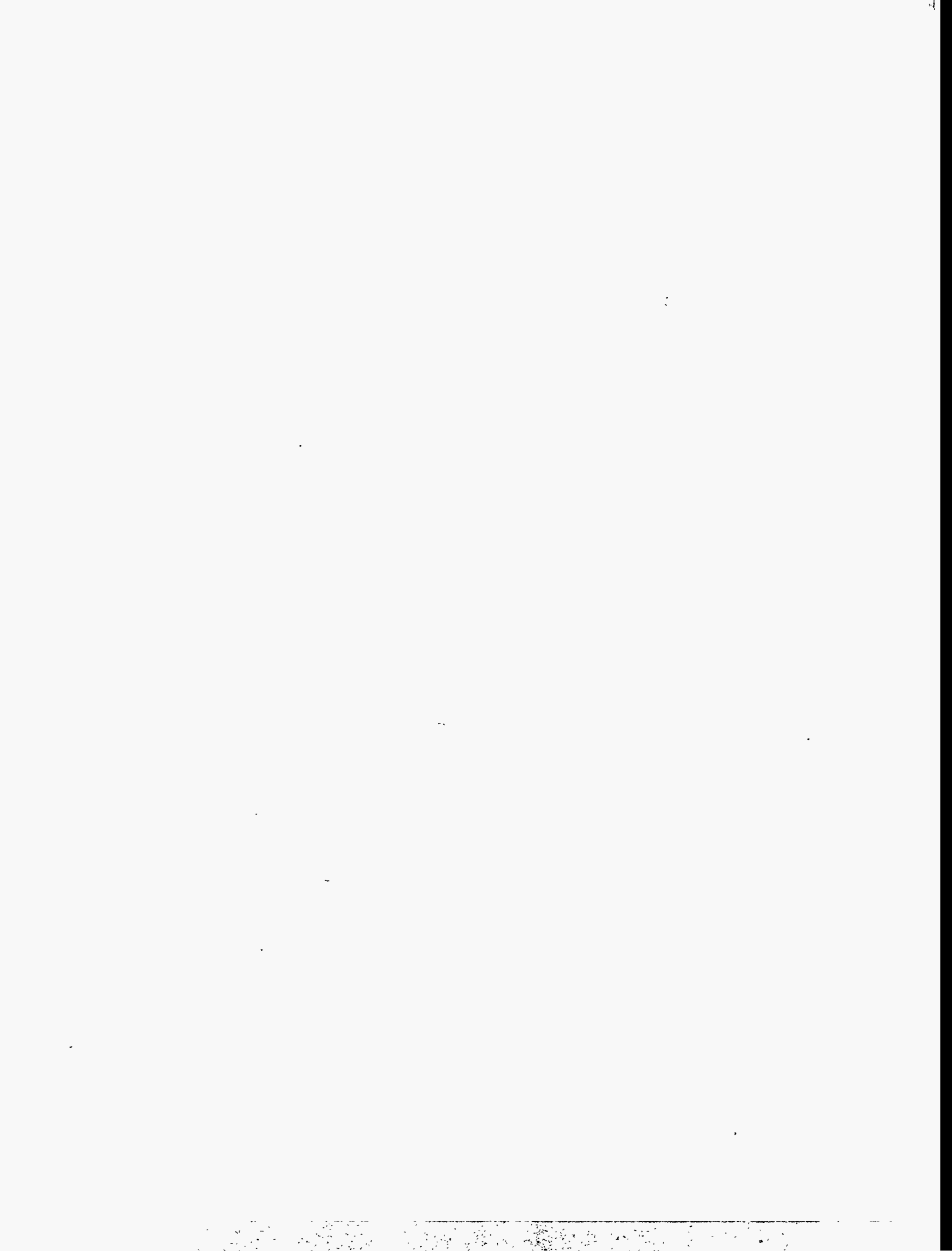
mulcomp

NAME: _____

CLASS PERIOD: _____



Please put the word that you think fits best in each of the blank ovals and rectangles. You may use the same word more than once.



Leader Directions: Nodes and links, generate

Here is a concept map like the one we saw about renewable energy sources. (Pass out the example concept maps from manila envelope.) What is different about this map? (Have someone point out missing concepts and links.) Can you think of some words that would make sense to put in the blanks? Can you figure out which concept words and link words would make sense to put in the blanks? (Let students fill in their maps and then discuss their answers.) It might help to read through the whole map to yourself first following the directions that the arrows are pointing. (Let students read and fill in their maps, then discuss their answers.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* rectangles and ovals are blank too. Here is our map. (Pass out copies of student map.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Now can you read the map and think of what link words and concepts to put in to make the map make sense? It helps to read through the whole map first, following the directions that the arrows are pointing. Can you figure out which concept words and link words would make sense to put in the blanks? (Let students fill in their maps and then discuss their answers.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

After students finish maps, collect pencils and hand out red pencils. Ask them to mark each of their answers according to whether they judged it to be easy (E), medium (M) or hard (H). Go on then to discussion questions:

DISCUSSION QUESTIONS:

1. (a) Pick your easiest answer. What made it easy?

(b) Pick your hardest answer. What made it hard?

2. (a) Is this a good way of showing what you learned from the video?

(b) What other ways could we use to show what we learned from a video?

3. (a) What did you like about doing this?

(b) What didn't you like about doing this?

(c) If you had a choice would you rather have a regular test, an essay test, or a fill-in concept map as a test in science?

If students wish, show the master map and discuss answers.

Leader Directions: Nodes and links, select

Here is a concept map like the one we saw about renewable energy sources. (Pass out the example concept maps from manila envelope.) What is different about this map? (Have someone point out missing concepts and links.) Can you think of some words that would make sense to put in the blanks? These missing words are listed at the bottom of the page. Can you figure out which concept words and link words would make sense to put in the blanks? (Let students fill in their maps and then discuss their answers.) It might help to read through the whole map to yourself first, following the directions that the arrows are pointing. See if you can put these words in the blanks on the map where they make the most sense. (Let students read and fill in their maps, then discuss their answers.)

We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* rectangles and ovals are blank too. Here is our map. (Pass out copies of student map.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Now can you read the map and think of what link words and concepts to put in to make the map make sense? It helps to read through the whole map first, following the directions that the arrows are pointing. The missing words are listed on the the page. Can you figure out which concept words and link words would make sense to put in the blanks? (Let students fill in their maps and then discuss their answers.) Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.

After students finish maps, collect pencils and hand out red pencils. Ask them to mark each of their answers according to whether they judged it to be easy (E), medium (M) or hard (H). Go on then to discussion questions:

DISCUSSION QUESTIONS:

1. (a) Pick your easiest answer. What made it easy?

(b) Pick your hardest answer. What made it hard?

2. (a) Is this a good way of showing what you learned from the video?

(b) What other ways could we use to show what we learned from a video?

3. (a) What did you like about doing this?

(b) What didn't you like about doing this?

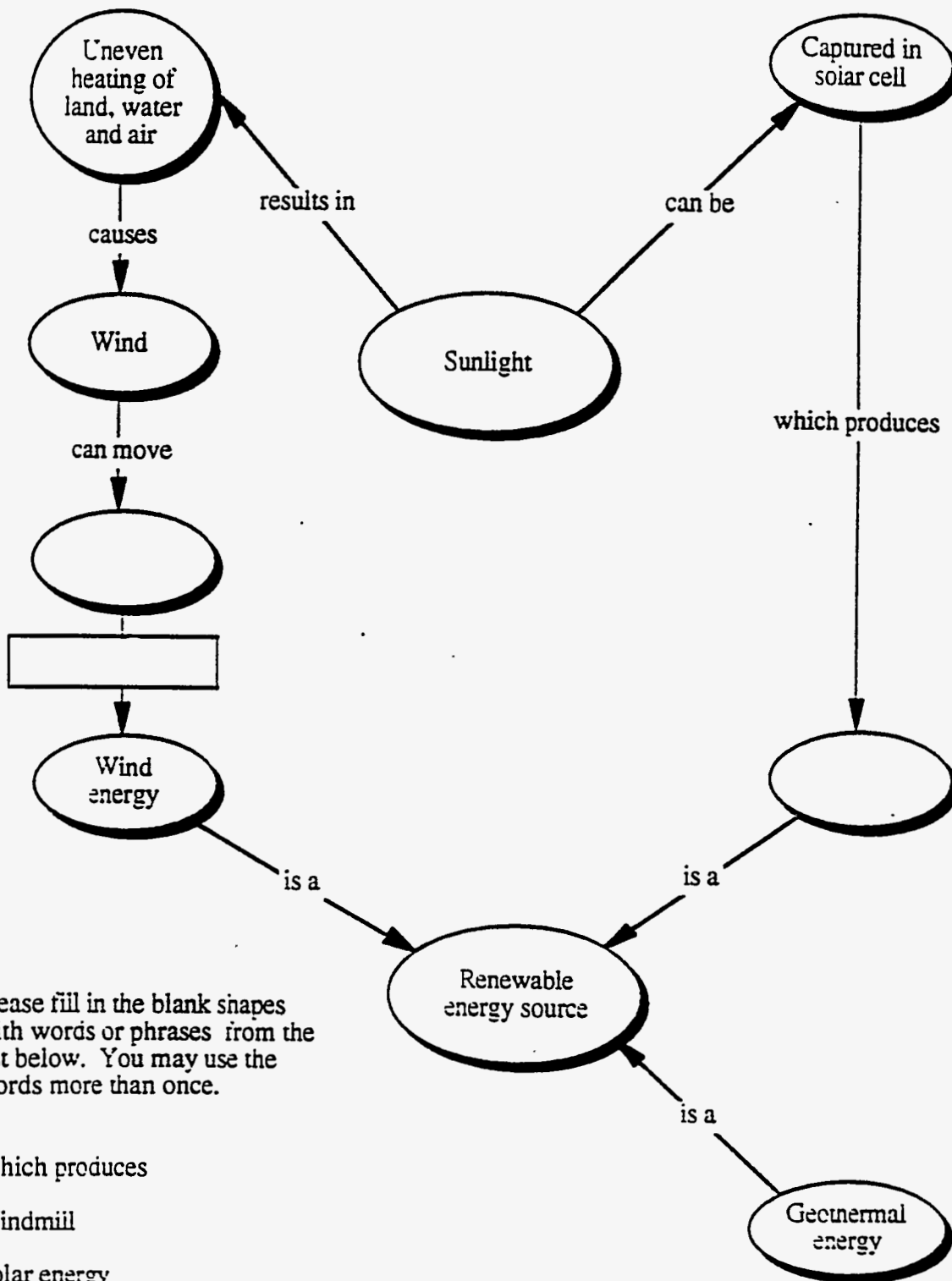
(c) If you had a choice would you rather have a regular test, an essay test, or a fill-in concept map as a test in science?

If students wish, show the master map and discuss answers.

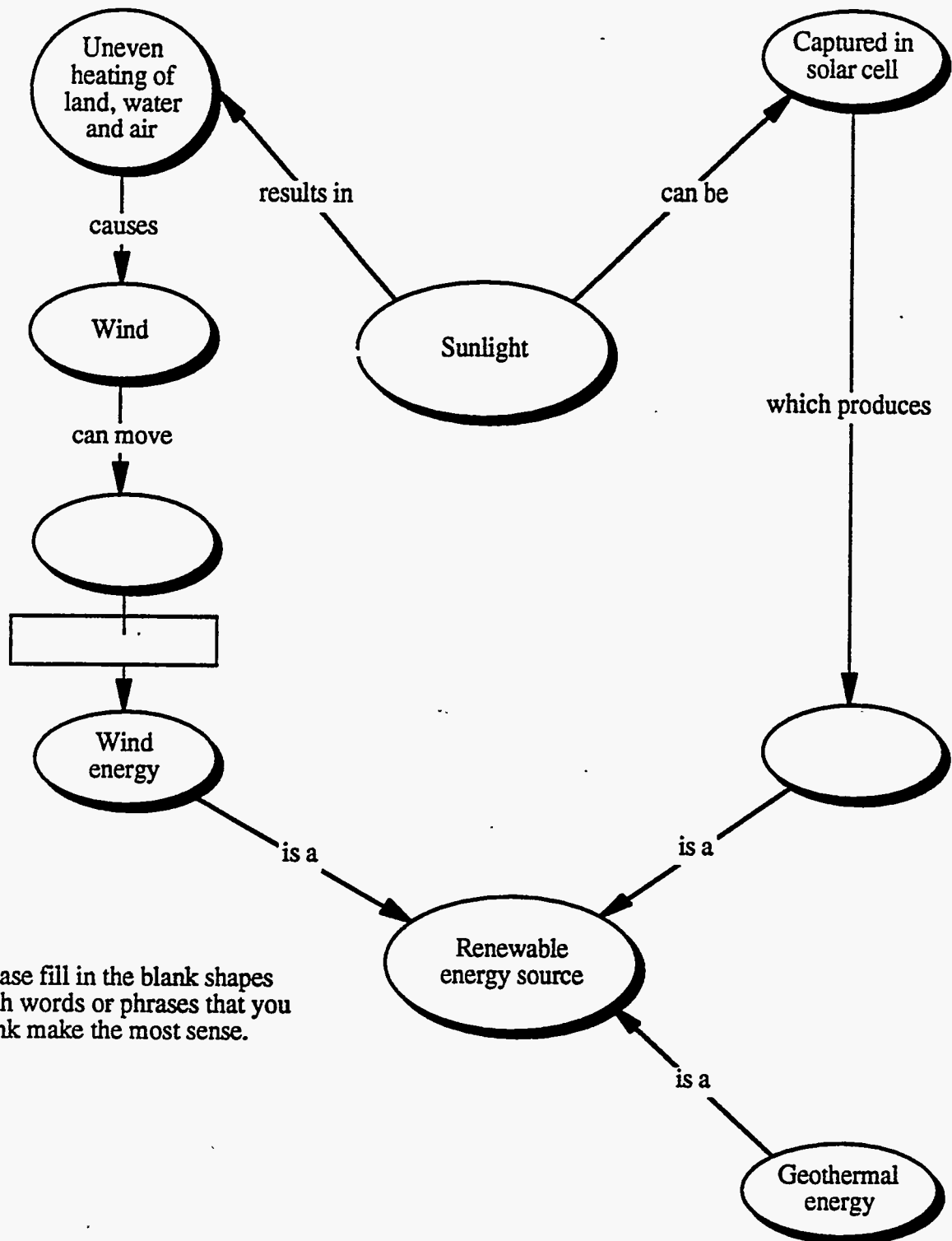
Leader Directions: Nodes and links, movable

Here is a concept map like the one we saw about renewable energy sources. (Pass out the example concept maps from manila envelope.) What is different about this map? (Have someone point out missing concepts and links.) Can you think of some words that would make sense to put in the blanks? Here are some words to try. (Pass out words from example envelope.) It might help to read through the whole map to yourself first, following the directions that the arrows are pointing. See if you can put these words in the blanks on the map where they make the most sense. Tape them down when you are finished placing them where you think they should go. (Let students read and fill in their maps, then discuss their answers.)

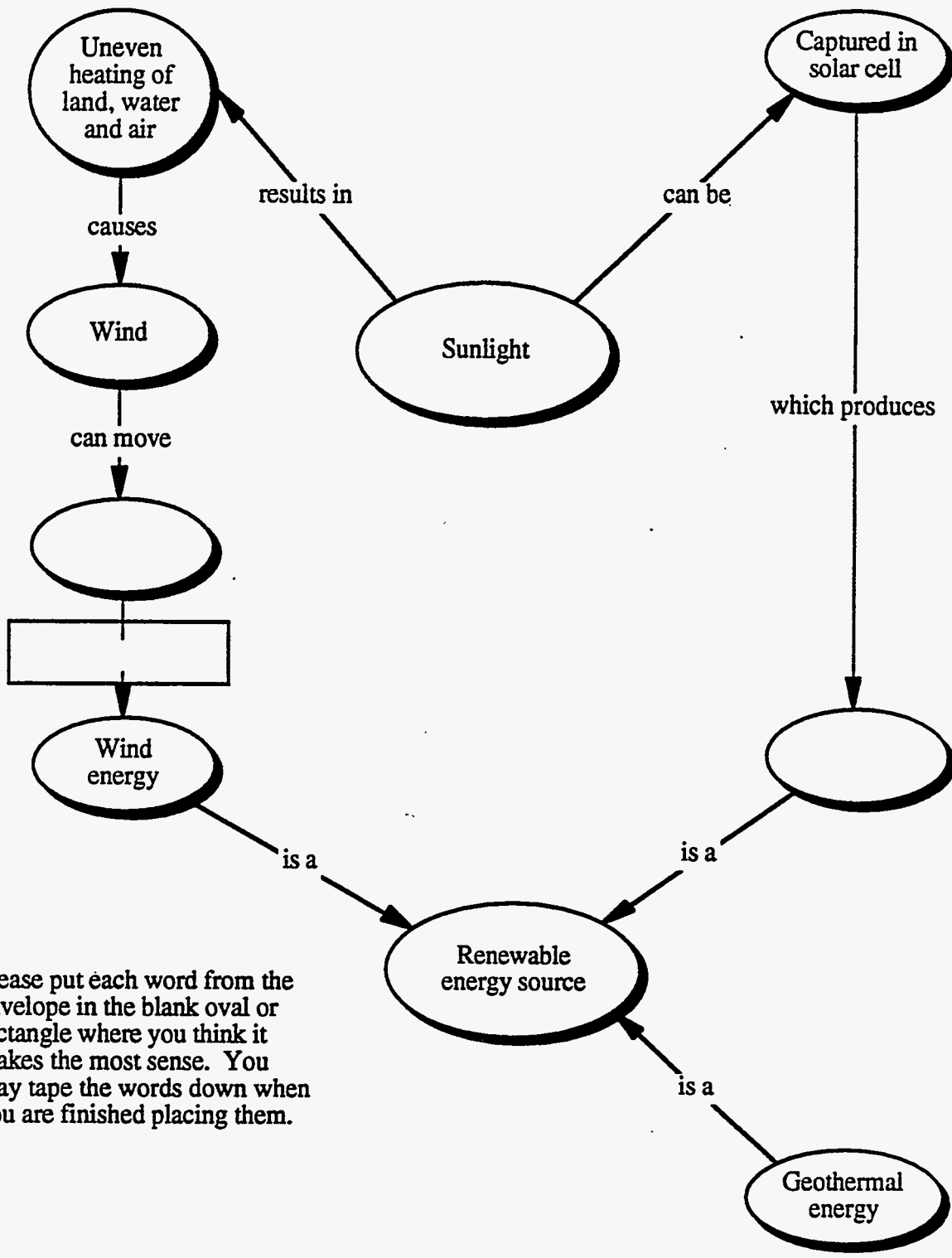
We drew another concept map to show some of what we learned about geothermal energy from watching the video. (Take out copies, but don't show them to students yet.) But some of *these* rectangles and ovals are blank too. Here is our map. (Pass out copies of student map.) First, please write your full name and the period # at the top of the paper. (Make sure all students have written their names.) Now can you read the map and think of what link words and concepts to put in to make the map make sense? It helps to read through the whole map first, following the directions that the arrows are pointing. Here is an envelope for each of you with the words. When you are finished placing the words where you think they should go, please tape them down on the paper. Each of you should work on your map by yourself. After you finish, we'll discuss them as a group.



Example 4



Please fill in the blank shapes with words or phrases that you think make the most sense.



Please put each word from the envelope in the blank oval or rectangle where you think it makes the most sense. You may tape the words down when you are finished placing them.

Solar energy

Which
produces

Windmill

Comes from

Solar energy

Which
produces

Windmill

Comes from

Solar energy

Which
produces

Windmill

Comes from

Solar energy

Which
produces

Windmill

Comes from

Solar energy

Which
produces

Windmill

Comes from

Solar energy

Which
produces

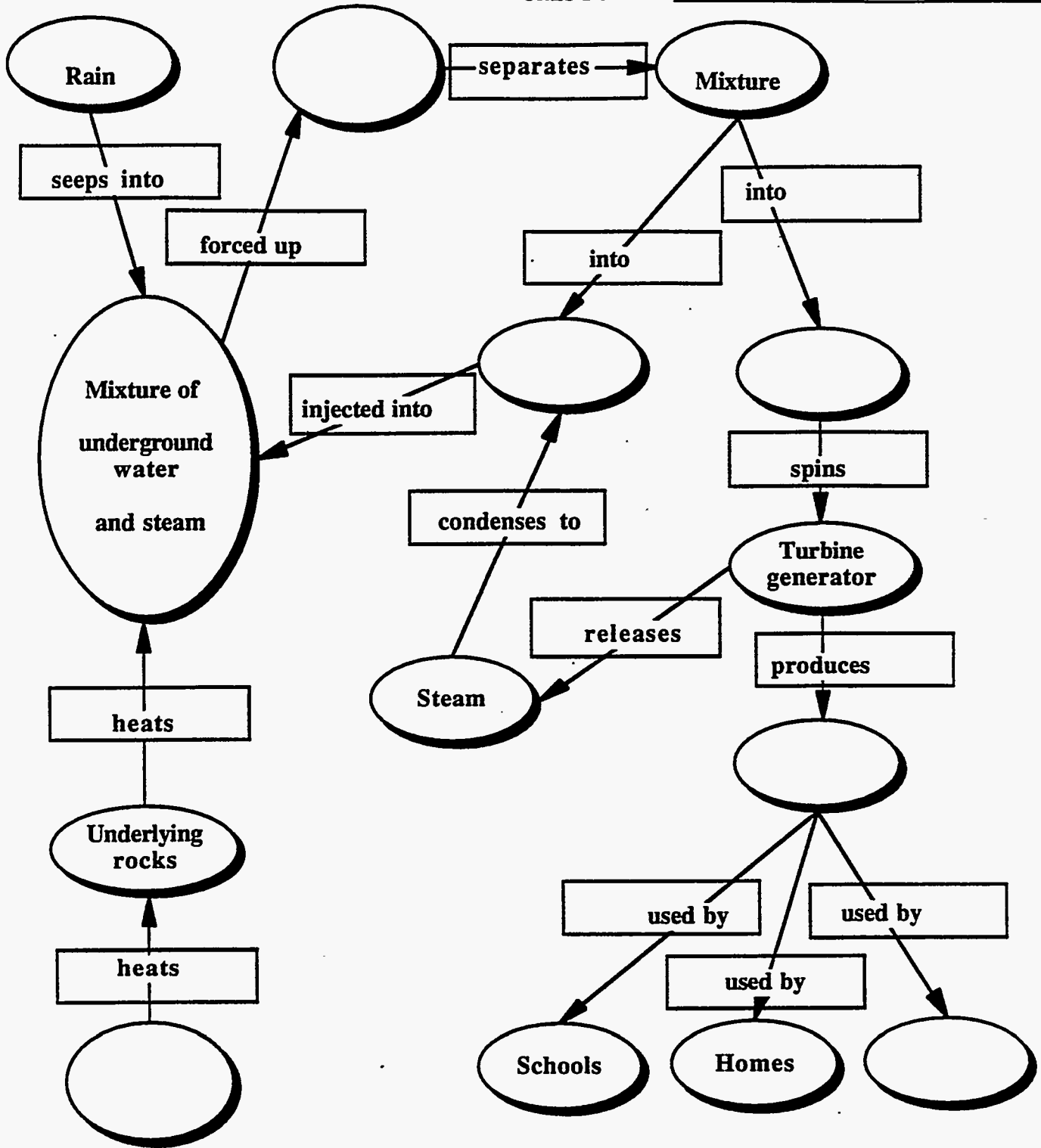
Windmill

Comes from

GEOHERMAL ENERGY

Name: _____

Class Period: _____



DIRECTIONS: Fill in each blank with a word from the list below. You may use a word more than once.

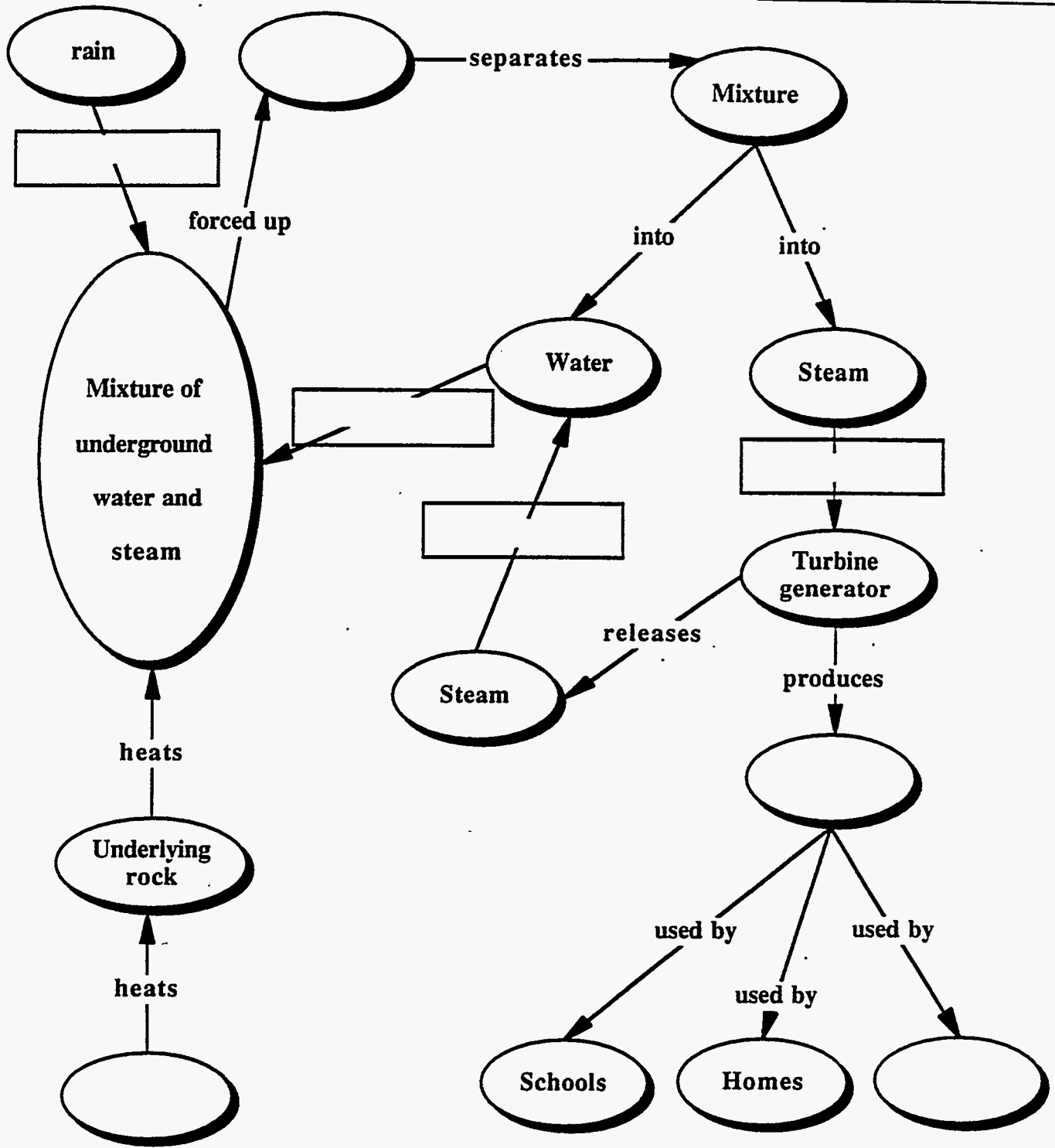
Electricity
Pipe
Factories

Water
Magma
Steam

GEOHERMAL ENERGY

NAME: _____

CLASS PERIOD: _____



DIRECTIONS: Fill in each one of the blank ovals and rectangles with one of the words below. You may use the words more than once.

Condenses to
Electricity
Injected into

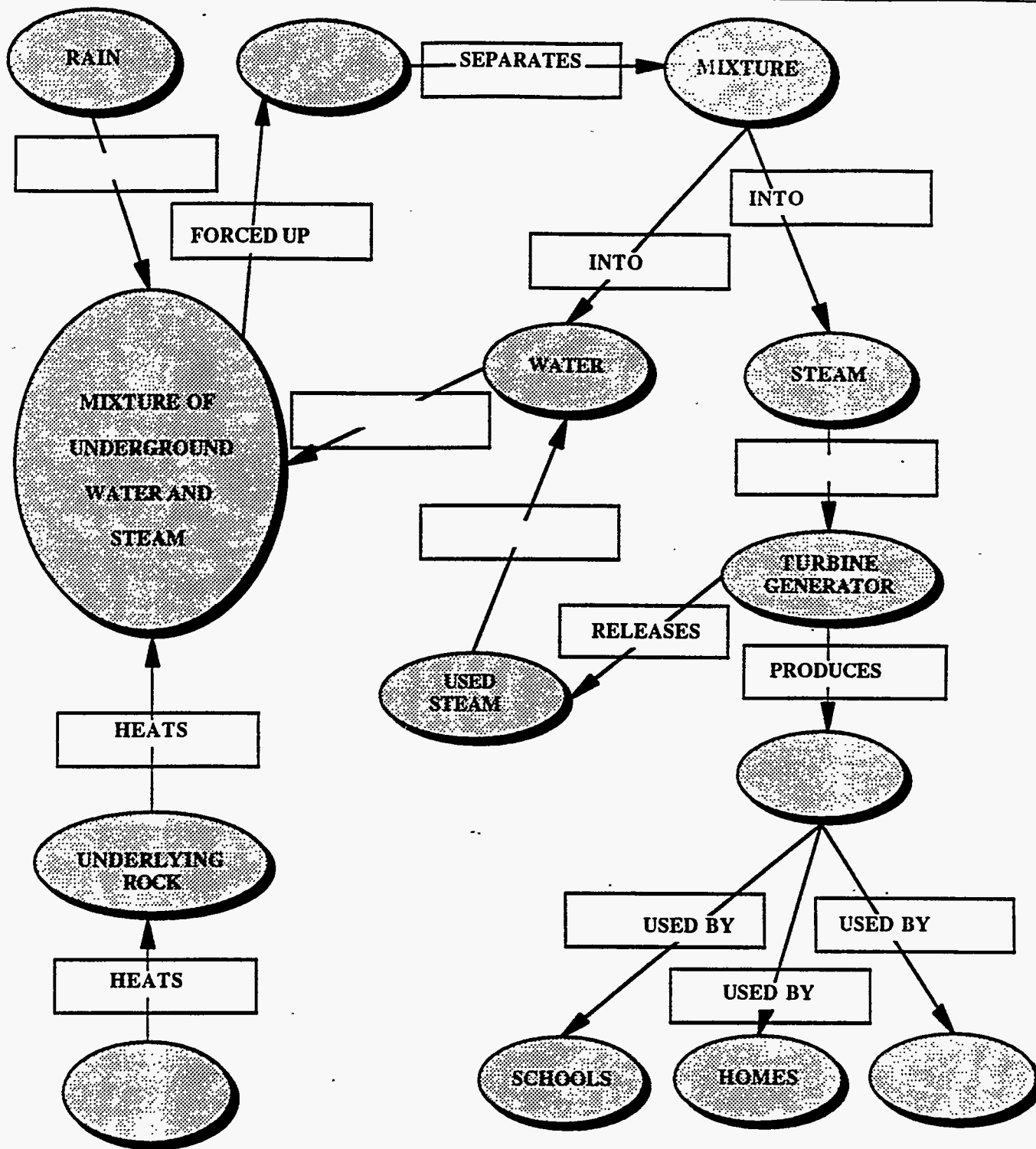
Spins
Factories
Magma

Seeps into
Pipe

GEOHERMAL ENERGY

Name: _____

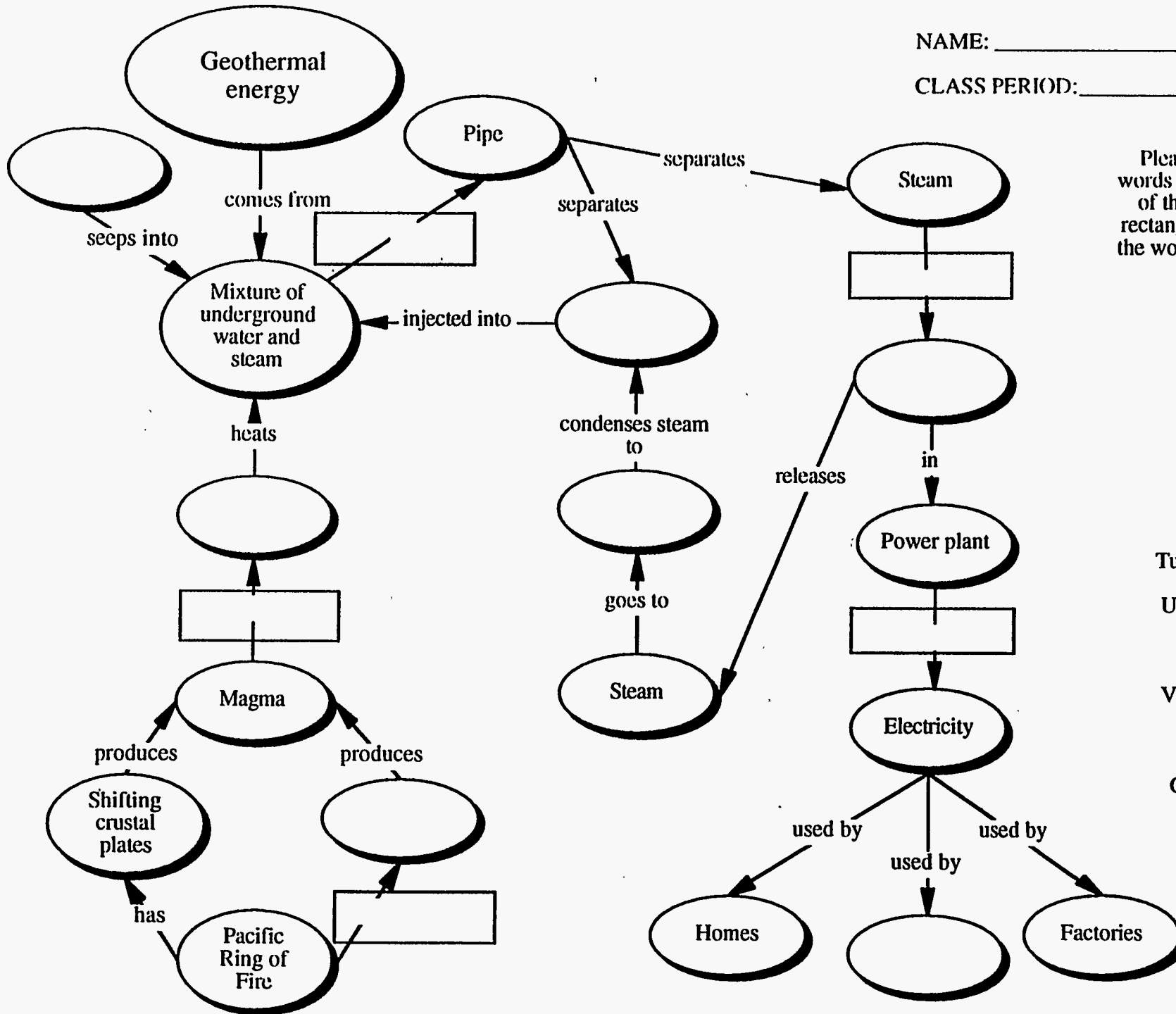
Class Period: _____



DIRECTIONS: FILL IN EACH BLANK WITH A WORD OR PHRASE THAT YOU THINK BELONGS THERE.

NAME: _____

CLASS PERIOD: _____

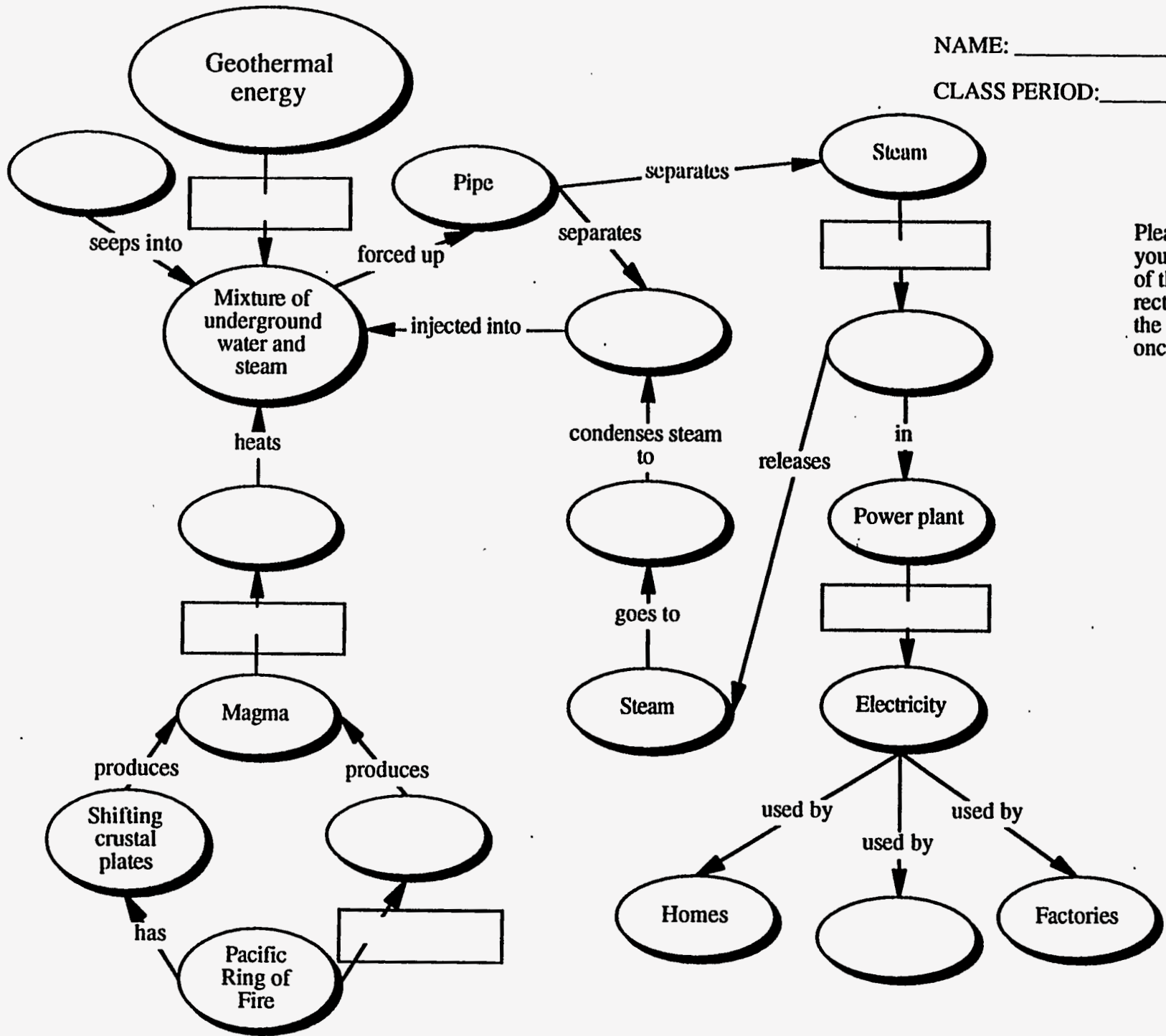


Please select from the words below to fill in each of the blank ovals and rectangles. You may use the words more than once.

- Heats
- Forced up
- Spins
- Water
- Produces
- Turbine generator
- Underlying rock
- Schools
- Volcanic activity
- Has
- Cooling tower
- Rain

NAME: _____

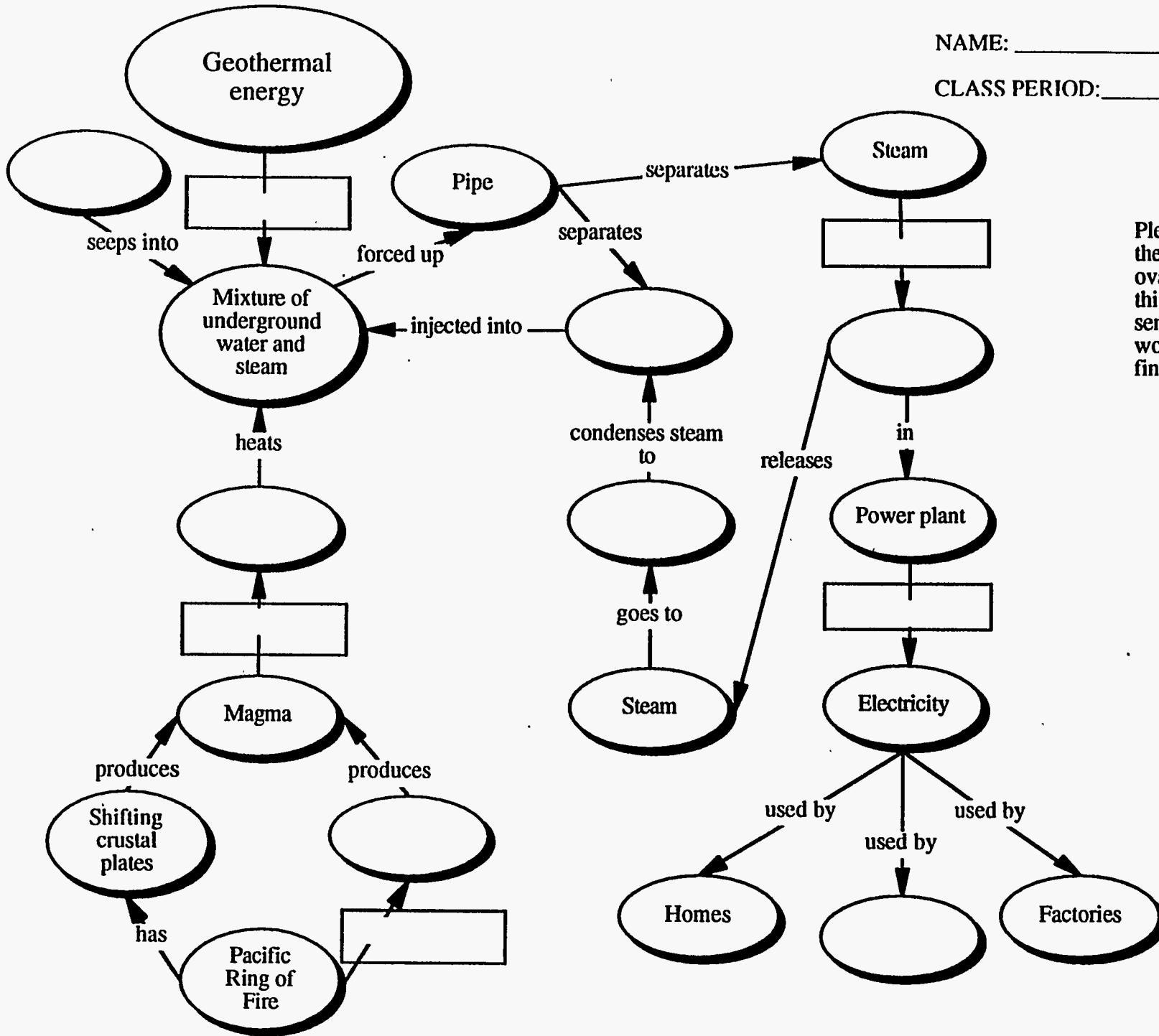
CLASS PERIOD: _____



Please put the word that you think fits best in each of the blank ovals and rectangles. You may use the same word more than once.

NAME: _____

CLASS PERIOD: _____



Please put each word from the envelope in the blank oval or rectangle where you think it makes the most sense. You may tape the words down when you are finished placing them.

Heats

Forced up

Spins

Water

Produces

Turbine generator

Underlying rock

Schools

Volcanic activity

Has

Cooling tower

Rain

Heats

Forced up

Spins

Water

Produces

Turbine generator

Underlying rock

Schools

Volcanic activity

Has

Cooling tower

Rain

Appendix III

Taos Map Assessment Formats and Directions

Names on board and introduce. We are working with a program called TOPS (on board); TOPS stands for Teacher Opportunities to Promote Science and is sponsored by Los Alamos National Lab. We are going to the schools of several teachers who have been part of this program. Mr. Romero was in the program and kindly agreed to help us with our TOPS work. We are asking for your help too.

We are working on how students understand science. There are different ways to look at understanding. For example, sometimes teachers ask you questions, sometimes they give you projects to do. We have developed some new ways of looking at how students understand science that are based on concept maps. Have any of you seen CMs before?

We tried out some of our ideas in another school. We used the feedback from those students to redo our maps. But we need your help to see how well the maps work now.

We will start by showing a short video on geothermal energy:

Some sources of energy are called non-renewable - once they are used up, they are gone (e.g., gas, oil);

Some are renewable - these sources don't get used up; geothermal energy comes from renewable energy sources.

There are other sources of renewable energy; this concept map shows some of them.

Look at the whole map; 3 pieces (ovals and arrows) point to RES.

Bottom is geothermal (GE & RES in ovals cause they are ideas; arrow from GE to RES that is labeled "is a" shows how these ideas connect); it's in video so we didn't add more to map.

Both other pieces start with SUNLIGHT; ME - go to right, then left.

So, overall, map tell us that 3 sources of energy are renewable and shows how sunlight produces solar and wind energy.

After we view video, each of us will work with one of you. First, each of you will do a concept map that is like this one. Then we will talk with you about doing the maps - how hard they were; how you decided what to do, what you liked about them, and so on.

Your CM will ask you about ideas that are in the video so you need to pay close attention to it. Our CMs are not tests, you won't get a grade on them. But it will help us a lot if you do your best. So let's begin by watching the video.

General Procedures (Taos)

1. Meet 3 middle school students and take them to the room we will work in.
2. Introduce our project, concept maps, and the video on geothermal energy to the students as a group: use same intro, etc., as we did at Cuba
3. Show the video to the group.
4. Split up into different areas of the room. One of us will work with each student.
5. Do our example with the student to help the student understand our map measure and to help the students become more comfortable with us and with talking aloud about problems they have solved. After completing the example (as we did it in Cuba), get your student to talk about the content on the map. Possible prompts include

Tell me what you know about wind/solar/geothermal energy.

Have you studied any of them in school?

Have you seen a windmill/solar cells? How do you suppose they work? What is good/bad about them?

Do you think people could use wind energy / solar energy here? Why do you think so (or not)?

Does NM have examples of geothermal energy? Where?

6. Have the student fill in our map, using the Cuba directions.

On your master map, RECORD THE ORDER in which they attempt the VARIOUS NODES AND LINKS; note HESITATIONS, use of LIST (select condition) or TRYING OUT PIECES in various places (moveable).
7. After the student completes the map, ask him/her to mark each answer as Easy (E), Medium (M), or Hard (H).

8. After student finishes, discuss the process (strategies used and, if possible, feelings about doing it. Possible prompts include

For GENERAL map

What do you think about this map? What does it tell you? What does it suggest to you/tell you about energy (how it is produced, used, affects environment, etc.)? (trying to discover whether students looking at individual pieces or map as a whole)

How did you know/figure out how to do this map?

How did you decide where to start/Can you tell me why you started here?
Would it have been easier to start _____?

What was easier/harder to figure out - the ovals or the rectangles? Why? Would it be easier to fill in all nodes first or all links?

What would make this map easier to do? harder to do?

What would make this map more fun to do?

Was there anything important in the video that isn't on this map? What?

What makes geothermal energy renewable?

For perceived DIFFICULTY level

How did you decide to mark these as Easy/Hard? Why did you mark ___ as Easy/Hard? What about ___ made it Easy/Hard?

For INDIVIDUAL responses

For correct answers:

How did you figure this one out? Was this the first answer you thought of?

For incorrect answers:

Did you have any idea what to put here? Why did you change your mind?
 What confused you?
 What would help you figure this out?

For RELATIONSHIPS like

"has" --> "volcanic activity"
 "heats " --> "underlying rock"
 "volcanic activity" --> "underlying rock"
 "turbine generator" --> "cooling tower"
 "spins" --> "turbine generator"

For correct answers

Did knowing _____ help you figure out _____? How?

For incorrect answers

If I told you that _____ was the correct answer, would that help you figure out _____?

What would help you figure this out?

For VOCABULARY

What does this word mean? What is it like?

condenses steam
 magma
 crustal plates
 turbine generator
 cooling tower
 seeps

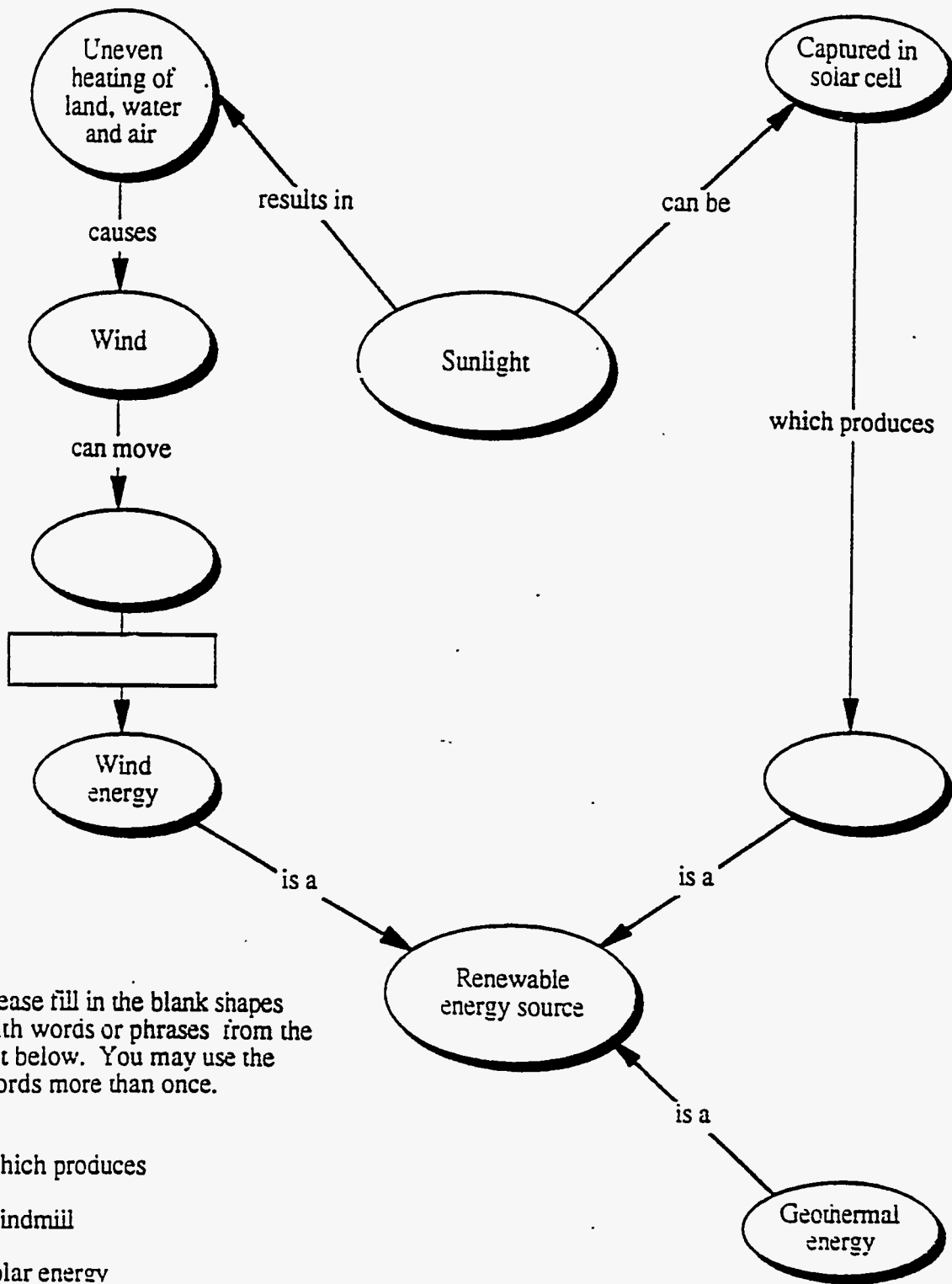
Give them a blank map. IF YOU WERE THE TEACHER

What would you say about this map to your students?

How would you get them started in filling it in?

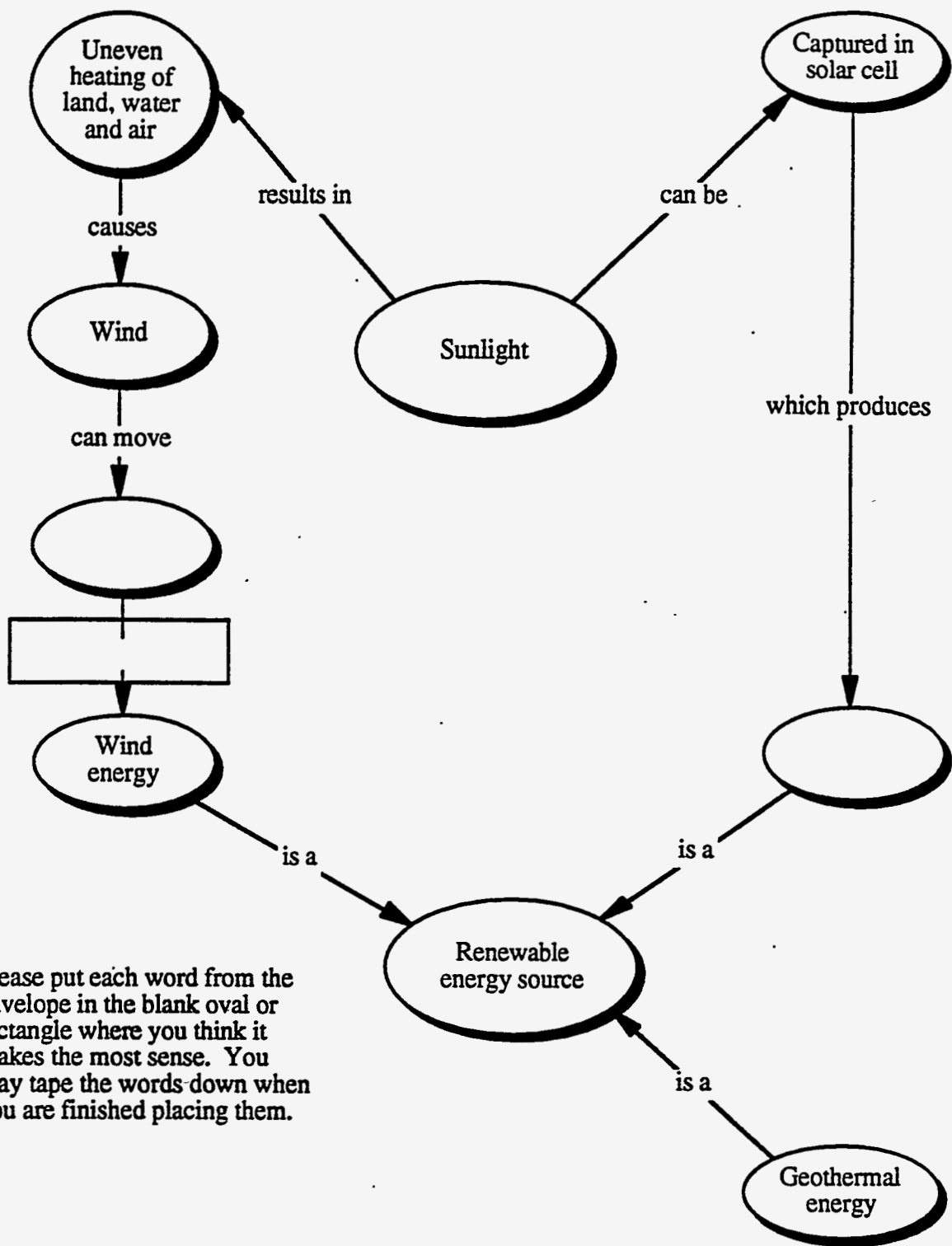
If you wanted to know about what your students learned from the video, would how they did on this map tell you anything about what they learned? What would be better ways to test students over what they learned from the video?

Using maps like this one, how would you do a project with the class on geothermal energy?



Please fill in the blank shapes with words or phrases from the list below. You may use the words more than once.

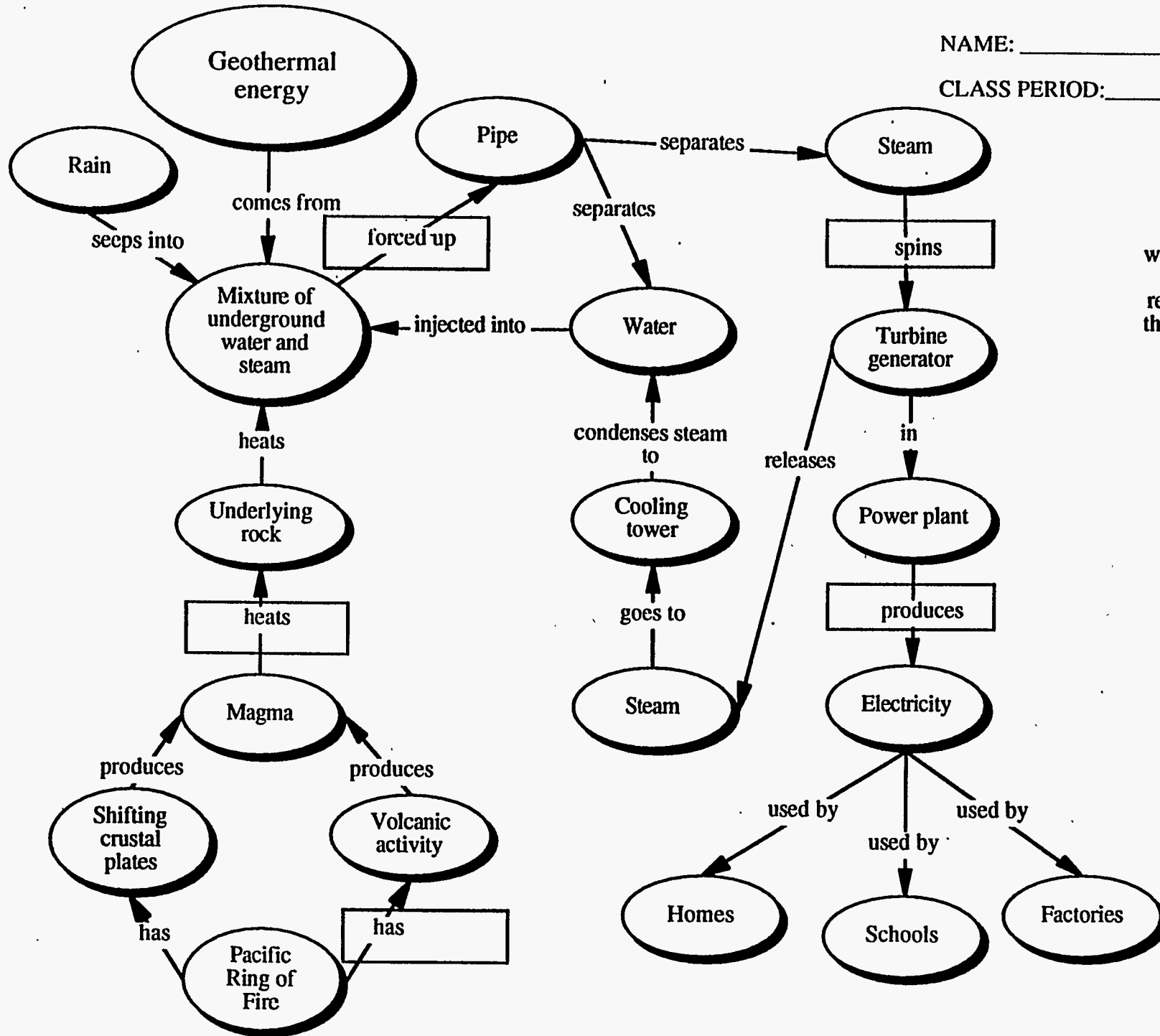
- Which produces
- Windmill
- Solar energy



Please put each word from the envelope in the blank oval or rectangle where you think it makes the most sense. You may tape the words down when you are finished placing them.

NAME: _____

CLASS PERIOD: _____

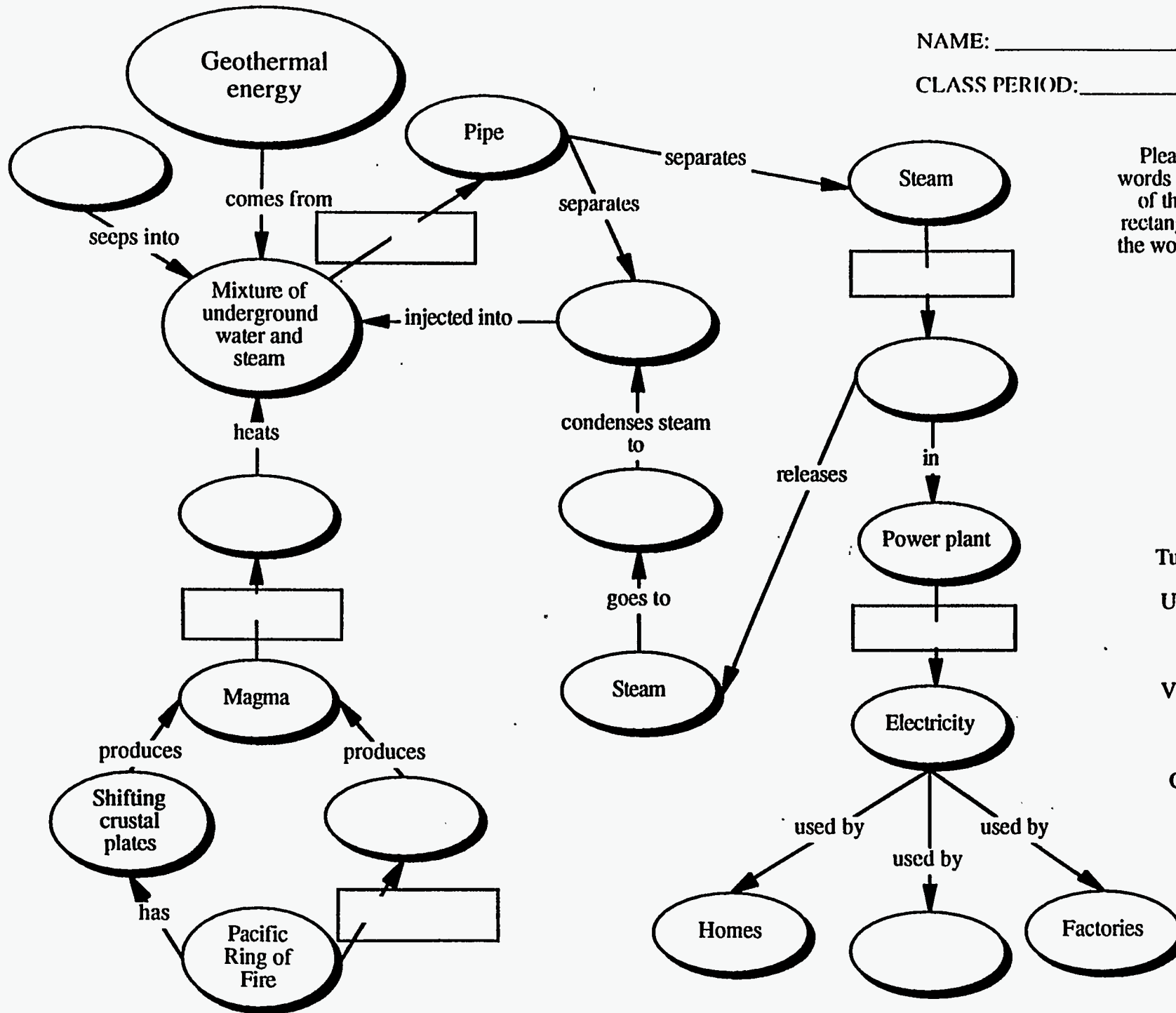


Please select from the words below to fill in each of the blank ovals and rectangles. You may use the words more than once.

- Heats
- Forced up
- Spins
- Water
- Produces
- Turbine generator
- Underlying rock
- Schools
- Volcanic activity
- Has
- Cooling tower
- Rain

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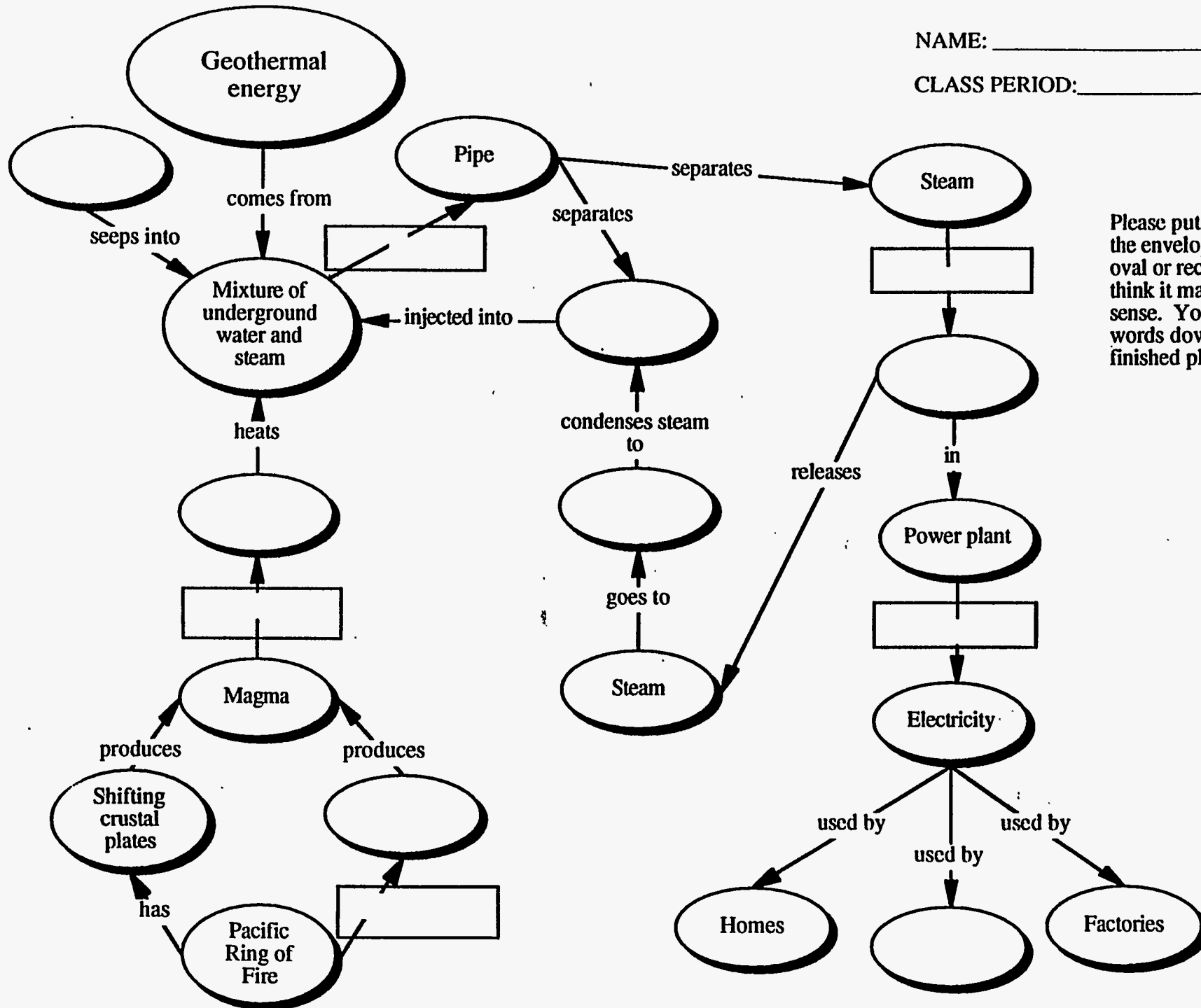


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