An Investigation of Problem Solving Tasks in Different Graduate Disciplines

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Abstract

One way to contextualize reasoning is to create assessment problems that embody critical features of the problems typical of a discipline. Problem characteristics are an important determinant of problem solving and reasoning processes. Critical problem characteristics are likely to vary among disciplines in relation to disciplinary differences in content, structure, and epistemology. However, no systematic or comprehensive description of problem categories and characteristics presently exists. A more abstract description of problems would contribute to the development of assessment problems that better match tasks performed in graduate school. It would also provide a basis for grouping disciplines in terms of critical problem characteristics so that assessment problems appropriate for broad areas rather than specific disciplines can be developed. The goal of this research was to develop a broad overview of problem solving tasks typically encountered in graduate education as well as a conceptual framework for classifying these tasks and their attributes. An overview of problem solving tasks was obtained through interviews with graduate students from six diverse disciplines and the collection of examples of problem solving tasks encountered in different contexts. A preliminary scheme for classifying these tasks was developed and provided a basis for rating scales to identify critical features of the tasks. Graduate faculty were interviewed about the appropriateness of the rating scales for characterizing problem solving tasks within their disciplines and about important student qualities. The implications of this study for developing new forms of assessment are discussed.
An Investigation of Problem Solving Tasks in Different Graduate Disciplines

An important goal of the research supported by the Research Committee of the Graduate Record Examinations (GRE) Board has been broadening the range of skills and abilities that are assessed, "so as to achieve a better match between the tests and the tasks that must be performed in graduate education" (Ward, 1988, emphasis added). Much of this research has focused on the analysis of skills and abilities important to success in graduate education (e.g., Enright & Gitomer, 1989; Powers & Enright, 1987; Tucker, 1985). However, once important skills and abilities are identified, designing assessment tasks that draw upon these skills and abilities and are an appropriate match to tasks performed in graduate school still remains a challenge. More systematic information about the kinds of problem solving tasks that graduate students confront would do much to meet this challenge.

Better knowledge about the nature of problem solving tasks in graduate education would have a number of benefits. First, such knowledge would represent a perspective on graduate education that complements the analysis of skills and abilities and more directly suggests suitable assessment tasks. The effectiveness of this approach is illustrated by the work of Frederiksen and Ward (1978), who drew on a study of critical incidents relevant to the evaluation of graduate students (Reilly, 1976) to develop tests of scientific thinking. Information that can lead to the development of new item types is particularly needed at present given the advent of computerized testing and enabling technologies that will increase the variety and complexity of problems that can be presented. Secondly, this knowledge would permit better evaluation of the match between assessment tasks and the actual tasks graduate students confront, thereby enhancing test validity. Third, this knowledge would be useful for comparing disciplines in terms of the problem solving demands they place on students and in improving the match between assessment tasks and discipline or domain requirements. Finally, the knowledge could be used to verify the appropriateness of the reasoning processes that are now being assessed and to identify additional reasoning processes for inclusion in the assessment.

The need for systematic descriptions of problem solving tasks can be seen by reflecting on the ways that assessment tasks have been designed in the past. Designing assessment tasks typically involves three levels of analysis, as illustrated in Figure 1 (Norback, Rosenfeld, & Wilson, 1990). The first concerns the real-world context in which people encounter problems and attempt to solve them. The second or conceptual level has typically involved an abstraction or generalization about the skills, abilities, or processes that are required to solve important tasks. The third level involves designing assessment tasks that are thought to require the identified skills, abilities, or processes. The steps in Figure 1, coupled with a program of validation research, are sufficient if what is desired is a test of decontextualized, general skills. An alternative viewpoint, however, is that assessment is more valid when aspects of the real-world context are preserved in the assessment context (Frederiksen, 1984). One response to the call for more authentic or contextualized assessment is to preserve many of the characteristics of real-world problems in the assessment. Assessment tasks are designed to simulate or imitate real-life problems, an approach that has been common in occupational assessment. In Figure 1, this approach is illustrated by a direct link between the real-world context and the assessment context. However, this approach may lead to tasks that are too tightly bound to highly specific contexts and that limit generalizability (Messick, 1994). One solution to this problem would be to identify critical features of the real-world tasks that permit the observation of important qualities and to preserve these features in assessment tasks. However, we lack frameworks that
Figure 1

Assessment Context

Conceptual Level

Real World Context

Assessment Items

Skills, Abilities, & Process

People Encounter Problems and Solve Them
allow discussions of problem characteristics at a more abstract or conceptual level. The need for a conceptual system to characterize problems may not be evident until one is faced with the challenge of trying to describe similarities and differences in problems across a variety of contexts. The goal of our research, as illustrated by the solid arrow in Figure 2, was to develop a conceptual framework for classifying the kinds of problem solving tasks typically encountered in graduate education that can serve as a basis for designing assessment tasks. An assumption underlying this approach is that problem characteristics are important determinants of the reasoning processes involved in the solution of a problem. Some evidence in support of this assumption is summarized in the next section.

Problem structure and its impact on reasoning. At present, generally accepted systems for describing or classifying problems do not exist. Rather, loose dichotomies (ill structured vs. well structured, convergent vs. divergent, verbal vs. quantitative, formal vs. informal) or unsystematic labels (diagnosis, interpretation, criticism) typically serve as descriptors of problem types. However, there are two recent discussions of how an information-processing model of problem solving (Newell & Simon, 1972) can be extended to describe the characteristics of different classes of problems (Goel & Pirolli, 1991; Perkins, 1990). According to Newell's and Simon's problem solving model, any given problem can be analyzed in terms of initial and goal states, operators that can be used to move from one problem state to another, and goal tests or evaluation functions that allow the problem solver to determine when the goal state has been reached. Furthermore, distinctions are often made between a problem representation or problem structuring phase, in which the problem solver formulates an interpretation of the problem situation and accesses relevant knowledge, and the problem solution phase.

Although much of the early work on problem solving was concerned with the solution of formal, well structured tasks, problem space analyses have been extended to account for ill structured, verbally complex problems (cf. Voss & Post, 1988). Ill structured problems have underspecified states, goals, and operations, and are typical of the kinds of problems encountered in everyday life. However, the contrast between "ill structured" and "well structured" is too broad to serve as a useful way of classifying problems. The need for a "problem theory," a descriptive system to classify problems, as a complement to "problem solving theory" has been discussed by Perkins (1990). He notes that such a theory would help us to understand (a) in what sense different kinds of problems are difficult or "problematic," (b) the distribution of different kinds of problems in different environments (such as academic disciplines), and (c) how different kinds of problems require different kinds of skills and abilities. Perkins proposes a system to classify a broad range of problems along multiple dimensions based on a problem space analysis. Perkins suggests that problems might be characterized along dimensions such as the stability of the problem (e.g., whether or not outside forces or events can change the problem as it is being solved), transparency (e.g., to what extent a problem solver has access to all the information needed to solve a problem), and simplicity (e.g., whether there are single or multiple paths to a solution, how much consensus there is about the suitability of a solution).

The power of a classification system based on a problem space analysis is more explicitly illustrated in the research of Goel and Pirolli (1991). They engaged in a program of research to describe the characteristics that distinguished design problems from puzzle-like, nondesign problems and to demonstrate how such distinctions in the task environment were related to differences in problem solution processes. One interesting aspect of this research is that
commonalities in design problems across disciplines (architecture, curriculum design, engineering) were described. Goel and Pirolli identified 12 characteristics that distinguished design from nondesign problems. Some examples of these distinguishing characteristics include (a) poorly specified problem states, goals, and operators; (b) both negotiable and nonnegotiable constraints in the task environment; and (c) a distinction between the specification of an artifact and the actual construction or delivery of the artifact. This latter characteristic means that a design is a plan but the problem solver is not expected to implement it or to produce the final product. This analysis of the characteristics of design problems served as the basis for specific hypotheses about differences in the problem solving and reasoning processes that would be apparent in the solution of design as opposed to nondesign problems. Empirical evidence for these hypotheses was obtained through analysis of verbal protocols from expert designers from different disciplines who were observed solving a simplified design problem in their field over a period of two hours. Hypotheses about the need for extensive problem structuring, distinct problem solving phases, decomposition of the problem, and specific control strategies received support from the empirical analyses.

The work of Goel and Pirolli (1991) is important in the present context for a number of reasons. First, they have demonstrated that distinguishing characteristics of certain types of problems, which are common to a number of disciplines, can be identified. Second, they provided empirical evidence of links between critical features of design tasks and specific problem solving or reasoning processes. Finally, they developed tractable design tasks that could be solved within a relatively short period of time (two hours). Such tasks seem to be at an appropriate level of "granularity" in terms of the commonalities in the problem structure across disciplines although the "granularity" of problem content may be too fine-grained for admissions testing. For our purposes, one limitation of this work is that only one class of problems was analyzed. Another is that there is no consideration of the relationship between discipline characteristics and problem characteristics. Are some types of problems more typical in some disciplines than in others? How do problem characteristics, other than type, affect reasoning processes, and are these differences systematically related to disciplinary differences? An accumulating body of research, briefly discussed below, is devoted to understanding the epistemology of various disciplines and the impact of disciplinary characteristics and training on reasoning.

Disciplinary differences and their impact on reasoning. Analysis of disciplinary differences in various epistemological characteristics is a topic of growing interest. Biglan (1973) had college faculty members rate the similarity of disciplines at their colleges and found that disciplines could be distinguished along three dimensions. These dimensions included (a) the existence of strong paradigms, (b) concern with applications, and (c) concern with life systems. More recently, Donald (1983, 1990, 1991, 1993) has engaged in an ambitious program of research that seeks to understand disciplines with respect to characteristics such as knowledge structure, learning tasks, validation processes, and truth criteria. For example, in one study Donald (1990) interviewed faculty members about the validation processes, truth criteria, and other validation factors characteristic of their disciplines. With respect to validation processes, Donald reported that the use of empirical evidence was emphasized in the natural and social sciences but not in the humanities. In contrast, peer review was a more important validation process in the humanities. Furthermore, faculty members in pure fields were more likely than those in applied fields to use conflicting evidence in validating their ideas.
Donald's work is particularly relevant in view of other research that documents how the structure and content of a domain are related to the processes involved in problem solving. Glaser, Schauble, Raghavan, and Zeitz (1992) observed student learning in three different computer-based discovery environments that embodied laws and regularities from the domains of microeconomics (law of supply and demand) and physics (electrical circuits, light refraction). The students' task was to induce the laws or regularities governing each environment. The nature of these regularities varies with the domain. Correlational regularities are characteristic of microeconomics whereas functional rules are characteristic of the two domains in physics. Glaser et al. documented differences in evidence-generation activities, interpretative activities, and the use of mathematical and algebraic heuristics that were associated with the nature of the laws governing each domain. This research complements the research of Goel and Pirolli described previously in that it identifies how one characteristic of a specific type of problem (discovery or inquiry) varies with domains and influences the kinds of problem solving and reasoning processes that are used in problem solution.

The Research Problem and Methodology

The previous discussion suggests that one way to contextualize reasoning is to create assessment problems that embody critical features of the problems typical of a discipline. Problem characteristics are an important determinant of problem solving and reasoning processes. Critical problem characteristics are likely to vary among disciplines in relation to disciplinary differences in content, structure, and epistemology. However, no systematic or comprehensive description of problem categories and characteristics presently exists. A more abstract description of problems would contribute to the development of assessment problems that better match tasks performed in graduate education. It would also provide a basis for grouping disciplines in terms of critical problem characteristics so that assessment problems appropriate for broad areas rather than specific disciplines can be developed.

The goal of this research was to develop a broad overview of problem solving tasks typically encountered in graduate education and a framework for classifying these tasks and their attributes. Such a framework would be useful for developing assessment tasks and could be developed through a number of methods. For example, one method for developing task frameworks in assessment relies primarily on the use of expert committees that, through discussion, arrive at a consensus about the kinds of tasks or the characteristics of tasks that should be included on the assessment instrument. This method links the framework only indirectly, through expert opinion, to an analysis of criterion tasks. Another method is job analysis. A typical procedure in job analysis is to interview one group of experts to construct a list of the knowledge, skills, and abilities (KSAs) thought to be necessary for competent performance and to survey another group to confirm the importance of these KSAs. These procedures are well suited to the development of assessments that measure many discrete skills. However, in the current study we sought to develop a framework that could be used to classify a sample of complex criterion tasks and that could support the development of more complex assessment tasks by delineating some of the critical features of the criterion tasks that would need to be preserved in the assessment context.

Methods for developing classification systems are not well established in psychology, though Fleishman and Quaintance (1984) have catalogued issues that need to be considered. These issues include (a) defining the purpose of the classification system, (b) deciding what
constitutes a task, (c) identifying a conceptual basis for the classification, (d) specifying relevant task attributes given the conceptual basis and evaluating their objectivity and reliability, (e) deciding on the structural characteristics of the classificatory system, and (f) evaluating the adequacy of the classification system.

Other issues we would add to this list include delimiting the domain of tasks to be classified, and collecting and describing a sample of tasks.

In the current study, we were concerned primarily with the issues of sampling and describing tasks, identifying a conceptual basis for classification, specifying relevant task attributes given this conceptual basis, and deciding on the structural characteristics of the classificatory system. A quantitative evaluation of the objectivity and reliability of the task attributes and the classification system will be the subject of future research.

Method

A broad overview of typical problem solving tasks in graduate education was obtained through in-depth interviews with graduate students from six different disciplines. A collection of samples of problem solving tasks provided a basis for the development of a framework for classifying tasks by project staff in consultation with internal experts (members of the Educational Testing Service test development and research staff) and external experts (graduate faculty in the selected disciplines). In addition, we interviewed graduate faculty about important qualities in graduate students and the kinds of situations in which such qualities were observed.

Disciplines were selected so as to maximize diversity in the sample of problem solving tasks. Another factor entering into the selection of disciplines was that large numbers of GRE examinees indicated in recent years that they planned to major in the fields. The disciplines included in the study were applied psychology, academic psychology, engineering, English literature, journalism, and physics. These disciplines represented the humanities, social sciences, and physical sciences as well as academic and applied disciplines.

We planned to interview a small sample (five students, five faculty members) within each discipline. First, graduate faculty who were willing to participate in the study were identified and they in turn suggested graduate students within their programs who might be interested in participating. After descriptions of participating faculty and students, the three major components of the study, (a) the collection of problem solving tasks from graduate students, (b) a preliminary classification system for academic tasks, and (c) the interviews with graduate faculty, will be discussed in more detail.

Participating Graduate Faculty and Students

Because the sample of faculty and students we planned to interview was small, we developed a set of criteria for participation directed toward obtaining a diverse sample so that different points of view would be represented. We sought to identify graduate faculty within each field who had some of the following characteristics: (a) a strong interest in graduate education, (b) a reputation as a particularly effective mentor, (c) an interest in recruiting and supporting graduate students from minority groups, (d) a position in a department that is
considered as one of the best places to do graduate work in a particular discipline at present, (e) a junior faculty member, and (f) a member of a minority group.

Initially, lists of potential participants were based on suggestions by staff involved in the development of subject area tests or by the chairpersons of large or well-known graduate programs. These individuals were then contacted by phone and asked to participate or to recommend colleagues having some of the characteristics listed above. A total of 30 graduate faculty members, five in each of the six disciplines, agreed to participate but five of these did not complete the study. No two graduate faculty members were from the same program or department. Although it was not always possible to enlist faculty members to ensure that each of the above criteria was met for each discipline, the faculty sample was reasonably diverse. Some characteristics of the faculty who participated in the study are presented in Table 1.

There were two aspects to faculty participation in this study. One concerned the application and critique of the rating scales. The second involved informal reflections about desirable and undesirable qualities in graduate students and the situations in which such qualities were likely to be evident.

Graduate faculty were asked to identify graduate students who might be interested in participating in this study. A total of 29 students agreed to participate in the study. Characteristics of the students who participated are described in Table 2.

**Student Interviews**

Two interviews were conducted with each student. The purpose of the first interview, which usually took an hour, was to identify examples of tasks that the student had completed in the course of graduate study. Fleishman and Quaintance (1984) note that the notion of a "task" is not well defined in the literature. Our concept of task was broad—a set of activities performed to accomplish a goal—rather than narrow, and assumed that a task has some objective as well as subjective aspects. Furthermore, we were concerned with tasks that had an externalized component such as a product or performance that could be evaluated by others. Thus, reading a book did not qualify as a task but writing a critique of a book would. Finally, our emphasis was on tasks that were completed in the first two to three years of enrollment in the program so that differences between tasks in master's and doctoral programs would not confound program characteristics with stage of education characteristics.

We developed a task-sampling framework to collect a comparable sample of tasks across students and disciplines to the extent possible. During our initial conversations with graduate faculty members, we had discussed both explicit and implicit requirements students were expected to fulfill in their graduate programs. This information was used to structure our initial interviews with the students. Students were asked to describe tasks they had carried out in the following contexts: (a) coursework including lectures, seminars, and laboratory courses, (b) teaching responsibilities, (c) research, (d) degree examinations, (e) internships and practicums, and (f) preprofessional and professional activities.
Table 1
Characteristics of Faculty Participants

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Number Participating</th>
<th>Years teaching graduate students</th>
<th>Number of women</th>
<th>Ethnic Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Psychology</td>
<td>5</td>
<td>3 - 30</td>
<td>3</td>
<td>Black (1) White (4)</td>
</tr>
<tr>
<td>Applied Psychology</td>
<td>4</td>
<td>22 - 30+</td>
<td>1</td>
<td>White (4)</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>3</td>
<td>4 - 12</td>
<td>2</td>
<td>Black (1) White (2)</td>
</tr>
<tr>
<td>English Literature</td>
<td>4</td>
<td>7 - 30+</td>
<td>1</td>
<td>White (3) Black (1)</td>
</tr>
<tr>
<td>Journalism</td>
<td>5</td>
<td>12 - 30+</td>
<td>1</td>
<td>White (5)</td>
</tr>
<tr>
<td>Physics</td>
<td>4</td>
<td>18 - 30+</td>
<td>1</td>
<td>White (4)</td>
</tr>
</tbody>
</table>

Institutions Represented

<p>| Columbia University           | University of California, Los Angeles |
| Cornell University           | University of Hartford               |
| Harvard University           | University of Iowa                   |
| Massachusetts Institute of Technology | University of Minnesota, Minneapolis |
| Northwestern University      | University of Missouri                |
| Pacific University           | University of Oregon                  |
| Princeton University         | University of Southern California    |
| Rutgers University           | University of Texas, Austin           |
| University of Arizona        | University of Virginia                |
|                              | University of Wisconsin, Madison      |</p>
<table>
<thead>
<tr>
<th>Discipline</th>
<th>Number Participating</th>
<th>Years in Graduate Program (Range)</th>
<th>Number of women</th>
<th>Ethnic Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Psychology</td>
<td>5</td>
<td>2 - 4</td>
<td>3</td>
<td>White (5)</td>
</tr>
<tr>
<td>Applied Psychology</td>
<td>4</td>
<td>2 - 3</td>
<td>3</td>
<td>White (4)</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>5</td>
<td>1 - 5</td>
<td>2</td>
<td>Asian Amer. (1) White (4)</td>
</tr>
<tr>
<td>English Literature</td>
<td>5</td>
<td>1 - 3</td>
<td>4</td>
<td>Black (1) White (4)</td>
</tr>
<tr>
<td>Journalism</td>
<td>5</td>
<td>1 - 8</td>
<td>3</td>
<td>White (5)</td>
</tr>
<tr>
<td>Physics</td>
<td>5</td>
<td>2 - 6</td>
<td>2</td>
<td>Asian Amer. (2) White (3)</td>
</tr>
</tbody>
</table>
With each student we identified 5 to 10 tasks for which they could send us sample materials and that would be discussed in more detail during the second interview. Examples of the materials collected are problems or questions from examinations, abstracts or sections from papers or reports, and notes for oral presentations. In the second interview, the students were asked to describe what was involved in completing each task with respect to the following considerations: (a) resources - what information sources were used (e.g., textbooks, journals, manuals, professors, other students, own knowledge); (b) activities and steps involved in carrying out the task; (c) definition and structure of the task - (e.g., how specific were directions for carrying out task, who defined problem to be solved, how was task completion determined); and (d) duration of task.

On the basis of these interviews a sample of 25 task descriptions was developed for each discipline. Tasks were selected for inclusion in the sample based on the quality of the information available about the task and in an attempt to include examples of major classes of tasks carried out in various contexts within each discipline. Examples of task descriptions from each discipline are included in Appendix A.

The Development of the Classification Framework

Two alternative methods of developing the classification framework were considered. One was to ask faculty to sort the tasks into categories of their own construction and to describe the features that distinguished different categories. The other was for project staff to develop a framework and embody it in rating scales for the faculty to use to characterize the tasks in the sample. It was decided that the former method might lead to a number of divergent classification approaches that would be difficult to interpret and to integrate. Therefore, the latter approach was used. The project directors developed a preliminary classification system and rating scales drawing upon problem solving theory, a previous attempt to classify academic tasks (Bloom, 1954), and an examination of the tasks that had been collected. The rating scales and the sample of tasks were reviewed by ETS test development staff with expertise in the disciplines of interest and the scales were modified in accordance with their suggestions. Graduate faculty were asked to use the scales to rate the sample of tasks from their disciplines and to comment on the scales' clarity and relevance to their disciplines. In addition, graduate faculty were interviewed about qualities they valued in graduate students and the situations in which these qualities could be observed.

Outcomes

The Sample of Problem Solving Tasks

Table 3 presents a summary of the kinds of tasks included in the sample for each discipline. The task contexts listed are those we used to structure our interviews. Tasks are categorized according to an obvious, traditional scheme that includes answering or writing discrete questions or problems, writing short (less than 5 pages) or long reports, writing proposals or outlines, or giving oral presentations. Most of the tasks in this sample were associated with course requirements, reflecting the study's emphasis on the first few years of graduate school when students often complete required courses. The most common kinds of tasks described involved answering questions or problems posed by a teacher and writing long papers or reports.
Table 3

Distribution of Sample Student Tasks by Category and Contexts for Six Graduate Disciplines

<table>
<thead>
<tr>
<th>Task Category</th>
<th>Context</th>
<th>Courses</th>
<th>Research</th>
<th>Teaching</th>
<th>Degree Examinations</th>
<th>Internships</th>
<th>Professional Activities</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Answer Questions/ Problems</td>
<td>AP - 6</td>
<td>EE - 1</td>
<td>EE - 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>AP - 6</td>
</tr>
<tr>
<td></td>
<td>BE - 10</td>
<td>EE - 2</td>
<td>EE - 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BE - 13</td>
</tr>
<tr>
<td></td>
<td>EL - 6</td>
<td>EE - 1</td>
<td>EE - 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EL - 8</td>
</tr>
<tr>
<td></td>
<td>JN - 5</td>
<td>EE - 1</td>
<td>EE - 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>JN - 5</td>
</tr>
<tr>
<td></td>
<td>PHY - 11</td>
<td>PHY - 1</td>
<td>PHY - 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PHY - 15</td>
</tr>
<tr>
<td></td>
<td>PSY - 6</td>
<td>PSY - 2</td>
<td>PSY - 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PSY - 8</td>
</tr>
<tr>
<td></td>
<td>All - 44</td>
<td>All - 2</td>
<td>All - 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>All - 55</td>
</tr>
<tr>
<td>Write Questions/ Problems</td>
<td>AP - 0</td>
<td>EL - 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>AP - 0</td>
</tr>
<tr>
<td></td>
<td>BE - 0</td>
<td>EL - 2</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>BE - 0</td>
</tr>
<tr>
<td></td>
<td>EL - 2</td>
<td>EL - 2</td>
<td></td>
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<td></td>
<td>EL - 2</td>
</tr>
<tr>
<td></td>
<td>JN - 1</td>
<td>JN - 1</td>
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<td>PHY - 1</td>
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<td>All - 1</td>
<td>All - 1</td>
<td></td>
<td>All - 5</td>
<td></td>
</tr>
<tr>
<td>Short Papers/ Reports</td>
<td>AP - 3</td>
<td>AP - 3</td>
<td>AP - 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>AP - 7</td>
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<td>EL - 3</td>
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<td>JN - 1</td>
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<td>PSY - 1</td>
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<td>All - 1</td>
<td></td>
<td>All - 19</td>
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<td>Long Papers/ Reports</td>
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<td>AP - 1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>PHY - 2</td>
<td>PHY - 1</td>
<td>PHY - 2</td>
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<td>PSY - 1</td>
<td>PSY - 1</td>
<td>PSY - 5</td>
<td></td>
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<tr>
<td></td>
<td>PSY - 1</td>
<td>All - 1</td>
<td>All - 2</td>
<td>All - 1</td>
<td>All - 1</td>
<td></td>
<td>All - 32</td>
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</tr>
<tr>
<td>Proposals/ Outlines</td>
<td>AP - 3</td>
<td>AP - 1</td>
<td>AP - 1</td>
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<td></td>
<td></td>
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<td>PSY - 2</td>
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<td>PSY - 3</td>
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<td>All - 7</td>
<td>All - 4</td>
<td>All - 1</td>
<td>All - 2</td>
<td>All - 1</td>
<td></td>
<td>All - 11</td>
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</tr>
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<td>Oral Presentations/ Lectures/Lead Group Discussions</td>
<td>EE - 1</td>
<td>EE - 3</td>
<td>AP - 1</td>
<td>AP - 1</td>
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<td>JN - 3</td>
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<td>PSY - 2</td>
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<td>PSY - 5</td>
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<td>All - 7</td>
<td>All - 5</td>
<td>All - 2</td>
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<td>All - 21</td>
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<td>Mac</td>
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<td>EE - 1</td>
<td>EE - 1</td>
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<td>AP - 0</td>
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<td></td>
<td>JN - 2</td>
<td>JN - 1</td>
<td>JN - 2</td>
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<td>PHY - 3</td>
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<td>PSY - 0</td>
<td>PSY - 0</td>
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<td></td>
<td></td>
<td>All - 7</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
<td>16</td>
<td>14</td>
<td>10</td>
<td>6</td>
<td>8</td>
<td>150</td>
<td></td>
</tr>
</tbody>
</table>

AP - Applied Psychology, EE - Electrical Engineering, EL - English Literature, JN - Journalism,
PHY - Physics, PSY - Academic Psychology
Because our sample of tasks is small and not random, inferences about the distribution of tasks among these disciplines in general cannot be made. However, one contrast among disciplines that was very salient in our interviews was the use of problems in electrical engineering and physics. According to the students we interviewed, much of their time in the first year or two of graduate school is spent solving sets of problems for course homework or examinations. This is reflected in the high incidence of the first task category for these disciplines in Table 3.

The broad categorization of tasks in Table 3 provides an overview of the kinds of tasks included in the sample but obscures the diversity that was present in the sample of tasks. For example, the category "short papers or reports" included book reviews, reviews of articles, reflections on readings or responses to presentations, and psychological evaluations of clients. To better analyze the diversity in problem characteristics that exists in this sample of tasks, we developed a preliminary classification system for these tasks and rating scales embodying the system.

Preliminary Classification System for Academic Tasks

The gross categorization of tasks in Table 3 does not even begin to suggest the kinds of task characteristics that could be used to guide the development of more complex assessment tasks. Although it is obvious that "written reports" vary greatly in their nature both within and across disciplines, delineating characteristics or features that underlie this variation is extremely challenging. Take, for example, the contrast between writing research reports and newspaper articles in a field such as journalism. Both assignments require "inquiry," posing questions, finding and evaluating evidence, synthesizing the evidence into a coherent written summary. However, the assignments may also differ with respect to many characteristics, such as whether the questions posed concern general issues or specific cases, the amount of time available to complete the assignment, or the kinds of information sources used.

To determine the distinguishing features of different kinds of tasks, we developed a rating instrument (see Figure 3). We asked the graduate faculty to use this instrument to rate the sample of tasks collected from students in their own disciplines and to comment on the instrument. Rather than ask faculty to categorize these complex tasks into discrete categories, the scales were constructed so as to allow multidimensional scaling of the tasks.

A problem solving framework provided the underlying rationale for many of the characteristics on the rating scales. Problem solving theory was used to suggest global differences among tasks, however, and not as a system to carry out a fine-grained comparison of problems in terms of possible representations and solution paths or of the states and operations involved in problem solution (cf. Perkins, 1990).

The classification system embedded in the rating instrument has three components. These include (a) general task requirements, (b) how well structured different phases of the problem solving process are, and (c) some contextual factors. The major characteristics on the rating scales correspond to classes of general task requirements, including, for example, analysis, inquiry, planning, and diagnosis. Although some of these goals have connotations in common with Bloom's (1954) cognitive objectives (e.g., analysis, application) they differ in that they do not represent a task demand for the use of certain cognitive processes; rather, they specify something about the nature of the problem solution the students are expected to produce.
Figure 3

Scales for Rating Features of Academic Tasks

**RATING SCALE**

To what degree is each of the following an appropriate characterization of the task. *(Please circle a number on the scale.)*

<table>
<thead>
<tr>
<th>Major Characteristics</th>
<th>SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consolidation</strong> - an important component of the task is to summarize, organize, or integrate information about, or to reflect on, a specific area of knowledge or topic.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td><strong>Analysis</strong> - task requires the analysis of a situation in terms of established principles, methods, classification systems, critical systems, or theoretical positions.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td><strong>Application</strong> - task requires the application of established principles, methods, classification systems, critical systems, or theoretical positions to the solution of a problem.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td><strong>Inquiry</strong> - an important component of the task is to search for, collect, and evaluate evidence in order to describe, interpret, or explain something.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td><strong>Systemization</strong> - an important aspect of the task is to elaborate or construct a system or structure within which information can be ordered, interpreted, integrated, or explained.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td><strong>Designs &amp; Plans</strong> - an important goal of the task is the development of a design, plan, or set of directions.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td><strong>Diagnosis/Evaluation</strong> - task requires the determination of what is wrong with a product, system, or set of ideas.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td><strong>Execution/Implementation</strong> - task involves the execution or implementation of previously developed plans or carrying out directions.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td><strong>Reflection</strong> - an important component of the task is self-evaluation or reflection about one's role in events or about what has been learned from an experience.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td><strong>Administration</strong> - task requires the coordination of activities of a number of people, and management of resources.</td>
<td>0...1...2...3...4</td>
</tr>
</tbody>
</table>

**Other Characteristics**

1. The task is highly complex. | 0...1...2...3...4 |
2. The task is a component of a larger task. | 0...1...2...3...4 |
### RATING SCALE

**Other Characteristics (continued)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. For the most part, the task is posed or defined by someone other than the student.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>4. Finding an important issue, topic, or question to consider would be a challenging component of the task for the student.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>5. An important aspect of the task is that the student needs to formulate a claim, thesis, or hypothesis.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>6. A number of different conceptual systems or approaches might be relevant to the task.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>7. Once a conceptual formulation of the task is achieved, the solution is straight-forward or routine.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>8. There are many alternative methods for accomplishing the task.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>9. In accomplishing the task, students must rely primarily on their current knowledge rather than consult a wide variety of other information sources.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>10. Explicit and objective standards exist for judging the quality of performance on the task.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>11. There are many different possible solutions for the task.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>12. The task requires interactions with colleagues, other professionals, or students.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>13. The task requires interactions with people other than colleagues, professionals, or students.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>14. The task is concerned with a particular instance, case, or example rather than with general issues.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>15. The task is very similar to the kinds of tasks that students will subsequently encounter in their professional careers.</td>
<td>0...1...2...3...4</td>
</tr>
<tr>
<td>16. Performance on this kind of task is likely to be highly informative about a student's professional development and potential.</td>
<td>0...1...2...3...4</td>
</tr>
</tbody>
</table>
These task requirements are more akin to general problem goals. The cognitive processes by which they are achieved would be expected to vary with the expertise of the problem solver. Because the tasks are complex, more than one requirement can be characteristic of a task.

Other items on the rating scales were intended to probe to what degree various aspects of the problem solution process, including problem finding, problem representation, and problem solution, were well structured or ill structured. A problem is ill structured when there are many open constraints that the problem solver must resolve in the course of problem solution (Voss & Post, 1988). Academic tasks may vary with respect to whether it is open for a problem solver to decide (a) what the problem is; (b) what principles, systems, theories, or perspectives might be applied to the problem; (c) which of many alternative solution paths should be taken; or (d) which of many alternative solutions may be best. A task would be well structured in any of these aspects to the degree that the range of alternatives available is limited or constrained by factors such as task instructions or the level of development of knowledge in the discipline. Scale items such as "For the most part, the task is posed or defined by someone other than the student" and "Finding an important issue, topic, or question to consider would be a challenging component of the task for the student" were included to determine the extent to which the student had to find or define the problem. Other characteristics were related to problem representation--"A number of different conceptual systems or approaches might be relevant to the task," and problem solution phases--"Once a conceptual formulation of the task is achieved, the solution is straight forward or routine," or "There are many different possible solutions for the task."

Some other aspects of the task environment, such as the variety of resources available and the need to interact with other individuals, were also included. Finally, the faculty were asked to rate how similar a task was to those students would encounter in future professional careers, and how informative performance on a task would be about a student's professional development and potential.

Faculty Reaction to the Rating Scales

Twenty-eight faculty were asked to rate the 25 task descriptions from their disciplines using the rating scales and were subsequently interviewed about their reactions to the scales. Three of these faculty members did not complete this task; two said they could not afford the time and the third did not respond to follow-up calls. Overall reactions to the rating task varied greatly. A few faculty members thought the task was very frustrating because they found the task characteristics vague and imprecise. Others found the task to be very interesting and mentioned that the opportunity to examine and reflect on a sample of tasks from their discipline was very stimulating. Faculty comments both on the adequacy of sample of tasks and on the items on the rating scales were solicited. Most of the faculty thought the collection of tasks was a representative sample of what students in their discipline did in the first two to three years of graduate school. A few comments on the adequacy of the task descriptions themselves were made. Faculty comments about task descriptions included the following--

- it was not always clear what aspect of a task was to be rated
- sometimes there was ambiguity as to whether to rate the task or the student's reaction to the task
there wasn't always enough information provided about a task.

With respect to the rating scales, faculty offered a wide variety of comments. For the most part, these comments concerned problems with the wording or clarity of the scale items (about 35% of the comments), overlap or redundancy among scale items (about 19%), and failure of scale items to discriminate among tasks (about 15%). A few scale items were described as particularly troublesome by a number of faculty. "Analysis" and "Application" were perceived as similar and undistinguishable. "The task is highly complex" and "task is a component of a larger task" were found to be ambiguous because a reference or anchor was not clear. Finally, the items concerning whether student tasks were similar to tasks professionals encountered or were informative about students' professional development were difficult to apply because of the wide variety of career paths students might follow.

These reactions suggest a number of ways that the rating task could be improved. Providing the raters with a statement about the basis for scale development and examples of how it should be applied to a variety of items would help reduce the ambiguity in many of the scale items. A quantitative analysis of the rating scales, which is currently being conducted in a follow-up study, will also contribute to a refinement of the scales and provide another source of information about the ambiguity, discriminability, and usefulness of individual scale items.

Important Student Qualities

In our interviews with graduate faculty, we also discussed what desirable and undesirable qualities they had noticed in students and the kinds of situations in which these qualities had been observed. We organized faculty comments about student qualities, both positive and negative, into four major categories that reflected cognitive, personal, interpersonal, and affective aspects of student behavior. Within some of the major categories, subcategories were constructed also. These categories and examples of the faculty comments that were assigned to a category are listed in Table 4. The number of faculty members in each discipline who made comments that were classified within each category also is provided in Table 4.

Most faculty comments about student qualities concerned cognitive aspects of student performance. We further subdivided these comments into seven subcategories, including (a) critical thinking, (b) creativity and originality, (c) flexibility, (d) learning ability, (e) synthesis, (f) writing skills, and (g) miscellaneous qualities. Comments about critical thinking abilities and about creativity and originality were most frequent and they were offered by faculty from almost all disciplines. The situations that faculty mentioned as providing an opportunity to observe evidence of critical thinking abilities included class discussions and seminars, written papers and reviews of articles, and comments made in grading undergraduate papers. Faculty noted that originality and creativity could be observed in proposals and research projects, papers, discussions, and in the approach students take to solving assigned problems.

A second major grouping of student qualities concerned personal characteristics. We recognized two subcategories here, which we labeled work-related qualities and intellectual self-confidence. Work-related qualities, such as industriousness, initiative, motivation, and persistence, were mentioned by 21 out of the 25 faculty members interviewed. Most
<table>
<thead>
<tr>
<th>Desirable student qualities and some examples</th>
<th>AP n=4</th>
<th>EE n=3</th>
<th>EL n=4</th>
<th>JN n=5</th>
<th>PHY n=4</th>
<th>PSY n=5</th>
<th>TOTAL n=25</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cognitive</strong></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Critical thinking - clarity and precision in criticism, question assumptions, develop logical arguments</td>
<td>1 0 3 1 1 3 9</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Creativity - ability to wonder, ingenuity, unique approach</td>
<td>1 1 2 3 1 2 10</td>
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<tr>
<td>Flexibility - apply diverse theories, open-minded, reformulate question</td>
<td>2 0 1 2 1 1 7</td>
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<tr>
<td>Synthesis - rework or reformulate knowledge, integration of ideas</td>
<td>0 0 0 2 0 3 5</td>
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<tr>
<td>Learning Ability - learn from mistakes, intellectual capacity</td>
<td>0 1 0 3 0 0 4</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Writing Skills - writing, clarity of expression</td>
<td>0 0 1 2 1 1 5</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Miscellaneous - notice patterns, broad range of interest, complex understanding of a situation</td>
<td>2 2 1 1 0 0 6</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><strong>Personal</strong></td>
<td></td>
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<tr>
<td>Work-Related - industrious, independent, initiative, organized</td>
<td>1 3 4 5 3 5 21</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Intellectual Self-Confidence - tolerance for errors, no fear of failure, not afraid of criticism</td>
<td>2 3 0 0 0 0 5</td>
<td></td>
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<tr>
<td>Interpersonal - easy to work with, empathetic, good communication skills</td>
<td>2 0 1 2 2 1 8</td>
<td></td>
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<tr>
<td>Affective - enjoys ideas, enthusiasm, dedication to field</td>
<td>4 0 0 2 2 1 9</td>
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</tbody>
</table>

AP - Applied Psychology, EE - Electrical Engineering, EL - English Literature, JN - Journalism, PHY - Physics, PSY - Academic Psychology
commonly, faculty suggested that these qualities could be observed in developing and carrying out research and other long-term projects. The other subcategory of personal characteristics, intellectual self-confidence, seems to reflect a capacity to risk criticism and to respond well to it and was evident in student presentations, papers, and proposals. These kinds of qualities were not as widely mentioned by faculty as were work-related ones.

Finally, the two other categories of comments, affective qualities, such as enthusiasm and dedication to one's field, and interpersonal skills, were much less frequently mentioned than were cognitive and personal qualities.

The information summarized in Table 4 is of limited generality because the small sample size and the informality of the interview procedure. Nevertheless, it does suggest important areas for further development in graduate admissions procedures. Critical thinking and creativity were the cognitive qualities most often mentioned by faculty members. The current GRE General Test includes a measure that is designed to assess reasoning skills. Whether or not the reasoning skills assessed by this measure are those involved in accomplishing the more complex tasks considered in this study is a construct validity question that can be answered by empirical research. The current examinations do not claim to assess creativity, although some item types (formulating hypotheses, Bennett & Rock, 1993) and measures (writing) now under development may be more sensitive to individual differences in creativity. Furthermore, in describing important student qualities, faculty were as likely to mention personal characteristics such as "independence/initiative" and "industrious" as they were to mention cognitive ones. At present, these characteristics in applicants are assessed informally through letters of recommendations, personal statements, and interviews. Research that documents the importance of these characteristics for success in graduate school and indicates ways to assess them more systematically may help to reduce overreliance on "cognitive" indicators that may limit access to graduate education.

A number of issues raised by faculty members concerning the possibility of including more complex assessment tasks on the GRE are worth mentioning. Although many faculty welcomed the idea, others mentioned a variety of concerns. Some faculty noted that they found the current GRE very useful, especially for students from little-known colleges or without recommendations from well-known professors. Another area of concern was whether complex assessment tasks would add to the burden of applying to graduate school and make the process even more complicated or onerous than it already is. Finally, a few faculty who described personality characteristics they appreciated in students also noted that characteristics such as "intellectual self-confidence" should be developed in graduate school and may not provide a good basis for selection.

Discussion

Does the future of graduate admissions testing include the use of more complex assessment tasks? There are a number of reasons why this question is being raised at present. One is the transition to computer-administered testing that will provide a platform for new kinds of assessment tasks. A second is concern about equity in admission to graduate school and the desire to explore the issue of whether new forms of assessment might provide evidence of aspects of student potential that are not documented by current admissions practices.
A third is the zeitgeist of the assessment community that sees in performance assessment a way to evaluate a broader range of skills. However, well-established methods, procedures, and standards for the development of complex assessment tasks for the purposes of predicting success in academic fields are lacking at present. Currently, the development of frameworks and specifications for academic assessments that include complex tasks often has an ad hoc quality. Such frameworks tend to be developed discipline by discipline in conjunction with committees of domain experts. What is absent from this approach is a more systematic analysis of the variety of tasks that are important in different disciplines, and the competencies that contribute to successful performance on these tasks.

In discussing the development of performance assessments Messick (1994) has noted that...

...a more principled approach is called for. There should be a guiding rationale akin to test specifications that ties the assessment of particular products or performances to the purposes of the testing, to the nature of the substantive domain at issue, and to construct theories of pertinent skills and knowledge (p. 14).

Given the possibility of using more complex tasks in admissions testing, there is a need to explore methodologies for the development of assessment frameworks. Messick (1994) has contrasted task-centered versus construct-centered approaches to performance assessment. He points out that one consequence of a task-centered approach may be a lack of generalizability because scoring rubrics are too task specific. On the other hand, construct-centered scoring rubrics may be too generic and fail to capture variability in performance that relates to differences among tasks or individuals.

The central purpose of the current study was to explore a task-centered approach as an initial step to inform the test design process. This approach involved an examination of the criterion domain of tasks in which graduate students actually engage. We collected a sample of tasks carried out in a variety of contexts from graduate students in different disciplines. The contexts included course work, research, teaching, degree examinations, internships, and professional activities. To counterbalance the tendency of such an approach to lead to a description of tasks that is too tightly bound to the original context and content, we developed a conceptual framework and rating scales based on this framework to identify some of the critical features of these "real-world" tasks that might be important to preserve in assessment tasks. Our ideas about critical task features were influenced by Bloom's taxonomy of cognitive objectives as well as by more recent work on problem solving theory. One important characteristic of the rating scales is that they were developed to be applied across disciplines. Another is that we will be able to evaluate the reliability and usefulness of the scales in different disciplines more formally in subsequent studies. Our expectation is that this framework could be used to group tasks into categories, to compare the characteristics of different categories of tasks both within and across disciplines, and to guide development of complex assessment tasks.

One important implication of this research for the GRE Program is whether test frameworks and specifications, especially for new initiatives, can be made more systematic and subjected to evaluation in the early stages of development. For example, test development committees might examine a sample of tasks from their discipline and identify critical features of the tasks. The usefulness and significance of these features for describing both criterion tasks...
and assessment tasks might be evaluated by having a larger sample of domain experts classify tasks using these features.

As an initial exploration of an alternative approach to the development of assessment frameworks, this study had some limitations. The collection of examples of problem solving tasks from students was very time-consuming. Sometimes we failed to elicit critical information or collected irrelevant information about the tasks from the students. In part, this reflected the fact that there is a circularity between the identification of critical task features and examination of the tasks. As the system for classifying tasks is refined, student interviews would be more focused on critical information. Another troublesome area was adapting a system of problem analysis, developed initially to describe a restricted class of tasks (well-structured puzzle problems), to a broad range of tasks. In addition, the specialized vocabulary associated with this system had to be translated into more generic terminology that may have resulted in a loss of clarity and precision. More detailed analysis of the application of the rating scales will establish whether our "translation" was meaningful to graduate faculty or not. Finally, we recognize that the system we have proposed for classifying tasks is preliminary and incomplete. A significant avenue for future research would be to develop and evaluate alternative systems for classifying tasks.

Other implications for the GRE Program arose out of our discussions with graduate faculty about important student qualities. Critical thinking and creativity were the cognitive attributes most often mentioned by graduate faculty. Although the current GRE assesses critical thinking on the analytical measure, creativity is not assessed and would seem to be a construct that should be targeted by new forms of assessment. Another striking finding was the frequency with which faculty mentioned work-related personal qualities such as industriousness or initiative. The vast majority of faculty interviewed mentioned the importance of such qualities. Further research on the importance of such qualities and related topics, for example, how graduate admissions committees currently evaluate personal characteristics, might help to broaden access to graduate education.

In conclusion, this study represents a preliminary step in developing a method for describing and classifying tasks performed in graduate school. The value of this kind of research, at a time when the potential for diversifying what we assess is rapidly expanding, is to focus attention on potential changes in the substance of assessment that should accompany changes in technology of assessment.
References


Appendix A

Examples of Task Descriptions from Six Disciplines
Task Description

The student took a specialty examination. The two-hour exam consisted of 3 questions, all of which had to be completed.

Materials -

One question from the examination.

Social psychologists have emphasized that personality is constructed in social interaction and then, depending on the interactional circumstances, perseverates until further interactions require its reconstruction. Are there no limits, set by a person's personality or other givens, on the personalities that the individual can construct? Suggest what some of these limits might be, where conceptually they come from, and how they can be given a role in social psychological accounts of the social construction process.
PSY-14

Task Description

The student gave a presentation on her first-year research at a mini-convention of faculty and students. With the help of an adviser, the student had identified a research topic and designed a study. She developed a questionnaire, pretested it on a small sample, and then used it on a larger sample. After analyzing the data the student wrote a 25 page paper and prepared for an oral presentation.

Materials -

attached - first page of notes for oral presentation
My first year project explores the relationships between gender, instrumental and expressive self-schemas, and helping behavior.

1. Primary interests: explore gender & ways people help

One of my primary interests was to explore whether or not gender is related to ways people help others. In 1986, Alice Eagly and Maureen Crowley published a meta-analysis on gender and helping behavior. In the meta-analysis, it becomes clear that most of the research concerning helping behaviors has involved short-term encounters with strangers where help is needed (for example, a motorist is stranded because his car has broken down, or an old woman has fallen). In addition, most of the helping research has concentrated on willingness to help, but not ways of helping. Eagly and Crowley found that overall, men were more likely than women to help but the authors suggest that this finding may be explained by considering the types of helping situations that have been investigated. Typically, many of these short-term encounters involving strangers can be threatening to the helper. For example, if a car is broken down on a side street and it is 3am, of course it seems more likely that a man would be willing to pull over and try to help whereas a woman might question her safety and choose to continue driving down the road. One of my goals then was to study helping behaviors in situations that were not threatening to the helper.

In 1988, Eisenberg and her colleagues examined gender-related traits and helping strangers in non-emergency situations. They found that women were more likely to help strangers than men in a non-emergency situation.

In hopes to expand this area of research on gender and helping, I attempted to explore not only likelihood of helping, but
Task Description

As part of an internship at a testing center and outpatient clinic, the student had to interview a new client, write an intake report and present it to the rest of the staff.

Materials

attached - intake summary
Patient Name: [Redacted]

PRESENTING COMPLAINT: is a 33 year old, divorced, black mother of one who was referred by Easter Seals. The patient reports that she is depressed and that this started two years ago when she was diagnosed as having diabetes. At that time she was working at the YWCA as a housekeeper but subsequently was forced to quit because of complications with her illness. It was also at this time that she separated from her husband of several years. The patient states that she is still in love with him but does not want him around because he uses drugs and she does not want her daughter seeing this. Currently she lives with her thirteen year old daughter, who she feels has been hurt by all of this because they can no longer do the things they used to. She also claims that her daughter has had an "attitude" lately and she feels as if they are growing apart and she is losing her, which also upsets her.

RELEVANT HISTORY: The patient reports that at birth her biological mother left her at the hospital and she was subsequently taken in by a foster mother. She claims that her foster mother used to abuse her, both mentally and physically. For example, the patient reported that one time her mother hit her in the head machete and almost took out her eye. She feels that her foster mother would do these things to "make sure she remembered who was boss". At age eleven she found out about what her real mother and contacted her. She claims that they used to meet in the park every Wednesday until one day when she just did not show up. About five years later they had contact again and have remained in touch. However, she states that she is not close to her real mother and that they hardly ever talk. The patient claims that she does not care to keep in contact with her mother or her family because she has three close friends whom she considers her family. However, she states that she does want to know why her mother did not care for her but did for her 2 sisters, 2 half sisters and 5 brothers.

CURRENT MEDICAL STATUS: The patient has diabetes, high blood pressure, sleep apnea, and neuropathy. She takes medications for these illnesses but is not sure of the names.

MENTAL STATUS: Overall, the patient was easily engaged and made good eye contact. Her thoughts were clear and there was no evidence of glaring cognitive difficulties. Furthermore, the patient's affect was appropriate for the content of the conversation.

DIAGNOSTIC IMPRESSION:
Axis I: Dysthymia
Axis II: Deferred
Axis III: Diabetes, High Blood Pressure, Sleep Apnea, Neuropathy
Axis IV: Moderate
Axis V: present GAF 65  past GAF 70

TREATMENT RECOMMENDATIONS: The patient stated that she would feel more
comfortable in individual therapy because she is afraid how other people in a group will respond to her situation. However, the patient stated that if that is the best form of treatment for her she will consider going into a group.
Task Description

For a course, the student had to write weekly a critique of a journal article (2-3 pages). The student reported that this was an easy task because the articles weren’t very difficult.

Materials

attached - 2 page critique
The article "Long-Lasting Alterations in Behavior and Brain Neurochemistry Following Continuous Low-Level LSD Administration" by W. King and G. Ellison, examines whether or not the after-effects of continuous, low level administration of LSD in rats is greater than that of daily injections of the same amount of drug. This study could be of theoretical importance because many of the after-effects of LSD are similar to psychotic reactions of a schizophrenic type. The results suggested that LSD has persisting neurotoxic effects when administered in a continuous low-level fashion. After examining this article closely, I have discovered several issues that need to be considered while reading it.

The first issue that needs to be addressed has to do with the subjects. Although they were 69 albino rats, which makes them more homogeneous than human subjects, there was twice as many male rats represented in the study compared to female rats. Ethically, human's could not have been subjects in this study. Secondly, the subjects were not divided into groups that took cross gender differences into account. The 48 male rats were assigned to only the behavioral tests and the 21 female rats were assigned to only the autoradiography tests. Even though I am not an expert in rat physiology, I can imagine that the same dosage of LSD will effect both sexes in a different manner behavioral and neurologically. Therefore, not to have included both genders in the two different tests limits that tests results to that sex rat and possibly to
that sex in humans (but this is even a bigger generalization).

A second issue that needs to be addressed has to do with the tests themselves. In the open field test, used to assess for average social distance, two rats were placed in a circular enclosure with a flat black interior and a floor divided by white lines into 22 cm squares. The location of each rat was recorded every 12 seconds for 1 minute. In my opinion, after watching the subjects for a while it would be easy to miss a couple of seconds here and there, which in turn could effect the data, especially since this had to be done for twelve rat pairs over a period of ten days. Also, this data could have been easily fudged to make the results come out the way the experimenters wanted them to.

The third issue that needs to be addressed has to do with the fact that base rates were never established for any of the subjects social behavior. Although there was a control group, in an experiment such as this it would have been wise and fairly easy to have established base rates. The reason for this has to do with the fact that the authors were studying the after-effects of a drug. Thus, how can you know the after effects of LSD when you do not know how the rats behaved before the drug was administered.

Lastly, the authors concluded that their findings are congruent with earlier suggestions linking LSD's hallucinogenic effects with alterations in temporal and limbic structures. However, the authors do not say how hallucinations were defined by the behavior in rats. Thus, it is very possible that the alterations in the temporal and limbic structures were due to the LSD itself and not necessarily the drugs hallucinogenic effects.
Task Description

For a graduate seminar, the student prepared a 10 minute report, delivery of which was to be followed by 15 minutes of questions from and discussions among the seminar participants. The report is essentially an article-review: it presents the main argument of an essay in which a critic offers a feminist-structuralist interpretation of Charlotte Lennox’s *The Female Quixote*, and conveys some of the textual evidence offered by that critic.

Materials

First paragraph from notes for oral report -

Langbauer begins by noting that for 18th century authors, romance was everything the novel was not: "the contrast between them gave the novel its meaning," as "the utility of romance consisted precisely in its vagueness; it was the chaotic negative space outside the novel" (29). Lennox’s *Female Quixote* "structures its story on the contrast between the novel and romance," so that the "silly extravagances of romance that Arabella illustrates are meant as a foil for the novel's strengths" (29). Lennox thus points to the fictiveness of romance and defines the novel negatively as "real and true." She tries to define *The Female Quixote* as a stable and controlled novel in part by deriding romance as nonsense. Lennox thus displaces the fictiveness of all fiction onto romance and away from the novel.
Task Description

One of two papers written for a course. The student argues that, in Flaubert's *Madame Bovary*, characters and plot are not conveyed through the devices that, in the student's view, were conventionally used in the 19th Century Realist Novel, with the result that the reader must "follow the shifting narrative tone" in order to make sense of these elements. The student develops and supports this point through very close textual analysis of an English translation of Flaubert's work and through references to other critics' readings both of the passages analyzed and of Flaubert's work as a whole.

Materials

First paragraph of paper -

*Madame Bovary* begins *in medias res*, with no preamble to identify the narrator, and only the barest indication of setting, thus disorienting the reader and forcing him or her to look to the narrative tone for clarification and understanding. The indeterminate narrative voice moves in and out of the minds of the characters, and through their world with varying focal lengths, at times withdrawing altogether to offer an ironic comment. This indeterminacy requires a willingness on the part of the reader to follow the shifting narrative tone, without expecting the kinds of characterization usually found in realist novels. We understand these characters not through the typology of Balzac or the psychology of George Eliot, but from the way Flaubert's irony treats them. The reader must abandon expectations of a reasonable and readable world in *Madame Bovary*, and instead, follow the play of language in Flaubert's stylization.
Task Description

Master's thesis - Categorized newspaper stories using a computer program and checked its reliability against human coders. The project took the student about 5 months and resulted in a 70-page paper.

The student developed the idea for topic in an earlier course. He then wrote a 20-page proposal including literature review and a description of the methodology and discussed the proposal with advisers. Conducting the research involved collecting a sample of newspaper articles, developing a categorization system, identifying key words in stories to be used as basis for categorization, developing a simple computer program to count occurrences of keywords and to categorize stories. The computer program was used to categorize stories and the student's colleagues also categorized the same stories. A statistical analysis comparing agreement of computer and human categorization was conducted. During this project the student met frequently with two advisers to discuss progress. The report was written up in stages as work progressed.

The most difficult aspect of the project was that the student had a general idea but found it difficult to conceptualize what he wanted to do more specifically.

Materials -

Abstract

Traditional methods of categorizing newspaper stories use human coders. Using a keywords list, analyses can be made by a computer program with high reliability and an absence of bias. The program, called GENCA, analyzed 609 randomly selected news stories from seven newspapers, classifying 95 percent of them into nine categories of news. As a check on reliability, five human coders classified 50 randomly selected stories, agreeing with GENCA an average of 72 percent. Agreement among themselves averaged 75 percent. GENCA agreed with at least one coder on all but six stories and agreed with the majority of coders in 82 percent of the cases.
Task Description

An item from a midterm examination. The student found the item relatively difficult because it required analysis using a particular system.

Materials -

**Item.** For the following hypothesis, provide concept names, a theoretical definition for each concept, an operation definition for each concept, a theoretical linkage for the hypothesis, and an operational linkage for the hypothesis. The hypothesis is:

The more television a person watches, the fewer books he or she reads.
Physics 1

Task Description

The student was given a final in-class exam. Twenty minutes were allowed to respond to each page of problems, one of which is attached. Resources included prior knowledge and internalized knowledge base.

The problem was considered of medium difficulty. The directions were very specific. The scope of the problems did not change as they were solved, and there were not alternative approaches to solution.

Materials

attached (one page)
(b) Derive the total angular momentum eigenstate $|\frac{1}{2}, \frac{1}{2}\rangle_{jm}$ from the fact that it must be orthogonal to the state you derived in (a). 

\[0 = \langle \frac{1}{2}, \frac{1}{2} | \frac{3}{2}, \frac{1}{2} \rangle = \frac{\sqrt{2}a + b}{\sqrt{3}} \]

\[a = -\frac{b}{2}, \quad \frac{b^2}{2} + b^2 = 1 \Rightarrow b = \sqrt{\frac{2}{3}}, \quad a = -\frac{1}{\sqrt{3}}\]

\[|\frac{1}{2}, \frac{1}{2}\rangle_{jm} = -10, \frac{1}{2}\rangle + \sqrt{2} \frac{1}{1, 1, \frac{1}{2}\rangle}\]

3. Still considering two particles, one of spin 1 and one of spin $\frac{1}{2}$:

(a) Construct in terms of $S^{(1)}$ and $S^{(2)}$ the projection operators $P_{3/2}$ and $P_{1/2}$.

\[J = S^{(1)} + S^{(2)} \quad J^2 = (S^{(1)})^2 + (S^{(2)})^2 + 2 S^{(1)} \cdot S^{(2)} \]

\[S^{(1)} \cdot S^{(2)} = \frac{J^2 - (S^{(1)})^2 - (S^{(2)})^2}{2} = \frac{1}{2} (J(J+1) - 1(J+1) - \frac{1}{2}(\frac{1}{2}+1)) \]

For $J = \frac{1}{2}$, $S^{(1)} \cdot S^{(2)} = -\frac{1}{2} = -1$; $J = \frac{3}{2}$, $S^{(1)} \cdot S^{(2)} = \frac{3}{2}(\frac{3}{2}) - 2 - \frac{3}{2} = \frac{1}{2}$

\[P_{3/2} = \frac{S^{(1)} \cdot S^{(2)} + 1}{3/2} \quad P_{1/2} = \frac{S^{(1)} \cdot S^{(2)} - 1/2}{-3/2} \]

So $P_{3/2} |\frac{1}{2}, \frac{1}{2}\rangle = 1$

$P_{1/2} |\frac{1}{2}, \frac{1}{2}\rangle = 0$

(b) Use the projection operators you found in 3 to construct directly the state $|\frac{1}{2}, \frac{1}{2}\rangle_{jm}$.

(If you could not do 3, indicate in general terms how, given such projection operators, you could construct the state.)

\[P_{\frac{1}{2}} \]

\[1 \quad |\frac{1}{2}, \frac{1}{2}\rangle_{jm} \approx \frac{-2}{3} \left[ S^{(1)} \cdot S^{(2)} - \frac{1}{2} \right] 10, \frac{1}{2}\rangle \]

\[2 \quad \frac{-2}{3} \left[ \frac{S^{(1)} S^{(2)} + S^{(1)} S^{(2)} + S^{(1)} S^{(2)}}{3} - \frac{1}{2} \right] 10, \frac{1}{2}\rangle \]

\[\rightarrow \quad \frac{-2}{3} \left[ \frac{1}{4} (S^{(1)} + S^{(2)}) (S^{(2)} + \frac{1}{2}) \right] 10, \frac{1}{2}\rangle \]

\[s_x = \frac{1}{2} (S^+ - S^-) \quad s_y = \frac{1}{2i} (S^+ + S^-) \]

\[\frac{1}{2}, \frac{1}{2}\rangle_{jm} \approx \frac{\sqrt{2}}{2} \left[ 10, \frac{1}{2}\rangle - \frac{1}{2} 10, \frac{1}{2}\rangle \right] \]

\[\text{Normalizing to } \langle \frac{1}{2}, \frac{1}{2} | \frac{1}{2}, \frac{1}{2} \rangle = 1 \text{, we obtain} \]

\[|\frac{1}{2}, \frac{1}{2}\rangle_{jm} = -10, \frac{1}{2}\rangle + \sqrt{2} \frac{1}{1, 1, \frac{1}{2}\rangle} \]

\[\frac{12}{\sqrt{2}} \]
Physics 21

Task Description

A student acting as a research assistant was given one month to generate a research proposal and resources listing. Resources included prior knowledge, internalized knowledge base, professors, other students, and articles. The steps included were: 1) researching the motivation...why do this experiment? 2) estimating or calculating the counting rates (how long it would take to do the measurement or gather the data), 3) deciding what equipment to use, 4) repeating #2 and #3 above for different types of equipment to optimize results, and 5) writing the proposal, using all this information.

The student found the task of medium difficulty. No information was provided with the assignment; the professor decided the topic, but the student did the rest of the structuring. The process changed as the problem was solved, but the formulas didn’t change. There were an infinite number of alternative approaches to solution. A harder problem might have involved trying to measure something that was harder to measure.

Materials

attached (2 pages; resources listing and introduction to proposal)
PROPOSAL INFORMATION

Beam Area: A

Secondary Channel: P3 West or East *

Beam Requirements:
- Type of Particle: π
- Momentum Range: 192 to 287 MeV/c (98 to 180 MeV)
- Momentum Bite: 1 to 4 % (Δp/p)
- Solid Angle: 7 msr
- Spot Size: 0.8-cm waists (FWHM)
- Emittance: Standard P3
- Intensity: (0.5 to 1.5) x 10^8 π⁻/s
- Beam Purity: Standard P3 performance
- Targets: Standard A2 target

Primary Beam Requirements: 800 MeV, 0.8-mA average proton beam

Time Required for Experiment
- Installation (no beam): one four week period
- Collection of Data: 128 hours
- Calibration and Normalization: 120 hours
- Degrader study: 24 hours
- Target manipulation: 24 hours

Total: 296 hours

Scheduling: Summer, 1991

Major LAMPF Apparatus required: Double Focussing magnetic spectrometer used in Exps. 99, 309, 337, 750, 783, 856, 859, 884 and 1026, rare gas handling system for ³He, LAMPF standard computer system and assorted NIM and CAMAC equipment from LEEP.

Shielding and Enclosures Required: Usual concrete shielding at P3 plus existing shielding for the spectrometer.

Special Services Required: 500-kW magnet power supply (2000 A at 250V) regulated to 10⁻⁴, 650°F deionized cooling water with Δp = 300 psi at 40 gal/min, cable tray between counting house and spectrometer, liquid nitrogen.

Space Required: Location for spectrometer in P³ West or East 54 in. downstream of final quad, or as close as possible, with power and cooling water delivered as in previous experiments and with space for ion chamber and profile monitor. P3 beam must be delivered to its dump without obstruction and the spectrometer must rotate freely.

* We prefer P³ West but only because the spectrometer can be placed closer to the last quadrupole and still rotate from 20⁰ to 130⁰.
Introduction

Although several experiments\(^1-^5\) have observed the isobaric analog transitions induced by pion single charge exchange in \(^3\)He and \(^3\)H, it is unclear what conclusions may be drawn from their results. At this time there is only one measurement at center-of-mass \(\pi^0\) angles forward of 80°, performed with the \(\pi^0\) spectrometer,\(^3\) at an incident energy of 200 MeV, and thus there is only one angle-integrated cross section available. The remaining experiments\(^1,^2,^4,^5\) all detected the recoiling nucleus, generally limiting their range of observation to angles greater than 80°. In addition, the recoil measurements at 200 MeV\(^1\) appear to be a factor of two or three times lower than would be expected from a smooth extrapolation of the forward-angle measurement at 200 MeV (see Fig. 1). However, because of the uncertainties in the absolute magnitudes of the reported cross sections, it is difficult to determine how serious the disagreement is. The existing experimental information on both the \(^3\)He(\(\pi^-,\pi^0\))\(^3\)H and the \(^3\)H(\(\pi^+,\pi^0\))\(^3\)He reactions is shown in Figure 2, along with cross sections calculated by Gerace et. al.\(^6\)

We propose to measure the \(^3\)He(\(\pi^-,\pi^0\))\(^3\)H differential cross section at incident pion energies of 100, 142, and 180 MeV and in an angular range of roughly 30° to 130° in the \(\pi^0\) center-of-mass system by detecting the recoil triton. These three energies are chosen to match energies at which reliable elastic scattering measurements have been made.\(^7-^9\) In this energy range the existing charge exchange data comprise three rather limited measurements of the charge-symmetric reaction \(^3\)H(\(\pi^+,\pi^0\))\(^3\)He.\(^2,^5\) A complete, systematic study of the charge exchange reaction at these energies should challenge theoretical calculation to describe both elastic scattering and single charge exchange at the same time. The measurements will be performed with a magnetic spectrometer, equipped with an array of silicon solid state detectors at its focal plane, viewing a cooled \(^3\)He gas target.

Scientific Motivation

The goal of this experiment is to study the pion-nucleon charge exchange reaction, \(\pi^- p \rightarrow \pi^0 n\), with the nucleon bound inside a nucleus. It is commonly accepted that three-body nuclear wave functions are well understood; therefore, the isobaric analog transition between \(^3\)He and \(^3\)H should be well suited to theoretical examination. A variety of methods has been employed to calculate the differential cross section for this transition.\(^6,^{10-17}\) While Glauber multiple scattering calculations \(^6,^{10,14}\) agree reasonably well with existing data above 250 MeV, optical potential calculations better describe the data below 200 MeV.\(^12,^{15-17}\) The poor agreement of the optical potential calculations with
EE 5

Task Description

The student was asked to write a manual as part of his research. He completed 2 1/2 months of research, and then spent 2 weeks writing the manual. Resources included prior knowledge, internalized knowledge base, the professor, and journal articles. Steps included reviewing previous research in the area, formulating their approach, writing a computer program to use as a modeling tool, and then, after the research was completed, writing the manual.

The student found the assignment medium-to-difficult. No information was provided about how to solve the problem.

Materials

attached (2 pages)
Foreword

The first section of this user's guide provides a description of UALGRL and the problems it can analyze. A tutorial that guides the user through an interactive session with UALGRL is also given in the first section. The second section of this manual is a reference guide to UALGRL. It provides a description of the input data required by UALGRL and the output data UALGRL can generate. Included in the reference section is a description of the error messages produced by UALGRL and their most probable causes and solutions. For the advanced user, a discussion of the mathematical models, their limitations, and implementation in UALGRL is also supplied in the reference section.

This version of UALGRL features the following improvements:

- Flexible input/output processing.
- User friendly mesh generation.
- Sources and sinks can lie on the edge of the plane.
- The plane can be divided into regions with different values of conductivity.

Please note that this font is used to indicate input and output from UALGRL.
Task Description

The student was asked to solve a homework problem. Resources included prior knowledge, the textbook, and class notes. The steps in solving it included: 1) formulating the word problem in terms of formulas, and 2) solving the formula.

The student found the task of medium difficulty. It would have been harder if the directions were less specific. The student was told what to use to solve the problem. The scope of the problem did not change as it was solved. There was only one approach to the correct solution to the problem.

Materials

attached (1 page)
52  SEMICONDUCTOR ELECTRONICS

1.11† Silicon atoms are added to a piece of gallium arsenide. The silicon can replace either trivalent gallium or pentavalent arsenic atoms. Assume that silicon atoms act as fully ionized dopant atoms and that 5% of the $10^{16}$ cm$^{-3}$ silicon atoms added replace gallium atoms and 95% replace arsenic atoms. The sample temperature is 300 K.

(a) Calculate the donor and acceptor concentrations.
(b) Find the electron and hole concentrations and the location of the Fermi level.
(c) Find the conductivity of the gallium arsenide assuming that lattice scattering is dominant.

See Table 1.3 for properties of GaAs.

1.12† (Dielectric relaxation in solids.) Consider a homogeneous one-carrier conductor of conductivity $\sigma$ and permittivity $\varepsilon$. Imagine a given distribution of the mobile charge density $\rho(x,y,z; t = 0)$ in space at $t = 0$. We know the following facts from electromagnetism, provided we neglect diffusion current:

$$\nabla \cdot D = \rho; \quad D = \varepsilon \varepsilon_0; \quad J = \sigma \varepsilon_0; \quad \nabla \cdot J = -\frac{d\rho}{dt}$$

(a) Show from these facts that $\rho(x,y,z; t) = \rho(x,y,z; t = 0) e^{-\gamma(t)/\varepsilon_0}$. This result shows that uncompensated charge cannot remain in a uniform conducting material, but must accumulate at discontinuous surfaces or other places of nonuniformity.

(b) Compute the value of the dielectric relaxation time $\tau/\sigma$ for intrinsic silicon; for silicon doped with $10^{16}$ donors cm$^{-3}$; and for thermal SiO$_2$ with $\sigma = 10^{-16}$ (Ω·cm)$^{-1}$.12

1.13† Because of their thermal energies, free carriers are continually moving throughout a crystal lattice. While the net flow of all carriers across any plane is zero at thermal equilibrium, it is useful to consider the directed components that balance to a null. The component values are physically significant in that they measure the quantity of current that can be delivered by diffusion alone. This would be relevant if, for example, one were able to unbalance the thermal equilibrium condition by intercepting all carriers flowing in a given direction. By considering that $J_x = -qn_0v_x$, show that the current in a solid in any random direction resulting from thermal processes is

$$J = \frac{-qn_0v_x}{4}$$

where $v_x$ is the mean thermal velocity and $n_0$ is the free-electron density.

(Hint. Consider the flux through a solid angle of 2π steradians.)

1.14* Calculate the wavelengths of radiation needed to create hole-electron pairs in intrinsic germanium, silicon, gallium arsenide, and SiO$_2$. Identify the spectrum range (e.g., infrared, visible, UV, and X ray) for each case.

1.15† The relation between $D$ and $\mu$ is given by

$$\frac{D}{\mu} = \frac{1}{q} \frac{dE_f}{d(ln n)}$$

for a material that may be degenerate. (That is, the Fermi-Dirac distribution function must be used since the Fermi level may enter an allowed energy band.) Show that this relation reduces to the simpler Einstein relation $D/\mu = kT/q$ if the material is non-degenerate so that Boltzmann statistics can be used.