Views About Science and Physics Achievement
The VASS Story

Ibrahim Halloun
Arizona State University & Lebanese University

The Views About Sciences Survey (VASS) is a paper-and-pencil instrument to characterize student views about knowing and learning science and assess the relation of these views to achievement in science courses. VASS shows that: (a) high school and college students have views about physics that often diverge from physicists' views, (b) student views can be grouped into four distinct profiles: expert, high transitional, low transitional, and folk, (c) profile distributions are similar in college and high school, and (d) student profiles correlate significantly with physics achievement.

Educational researchers have observed that students at all levels hold views about science that are at odds with the views they are expected to develop in science courses, and that student views may negatively affect achievement in these courses (1 – 6). We have developed the *Views About Sciences Survey* (VASS) to survey student views about knowing and learning science and to assess the relation of these views to student understanding of science. VASS was administered to thousands of high school and college students across the USA. This paper discusses major features and outcomes of VASS in physics courses.

VIEWS ABOUT SCIENCES SURVEY (VASS)

VASS assesses student views about the nature of science along three dimensions (*scientific dimensions*), and about learning science along three other dimensions (*cognitive dimensions*). Scientific dimensions pertain to the structure, methodology and validity of science. Cognitive dimensions pertain to learnability, reflective thinking and personal relevance of science. Each dimension is framed below in the form of pairs of contrasting views. The primary view is the one we found to be most common among scientists and educators. The opposing view is the one often held by the lay community and many science students at all grade levels. In the scientific dimensions, the primary views are characteristics of *scientific realism*; the opposing views, of *naive realism.* In the cognitive dimensions, the primary views are characteristics of *critical learning*; the opposing views, of *passive learning.*

Scientific Dimensions

1. ***Structure.*** Science is a *coherent body of knowledge* about *patterns* in nature revealed by *careful investigation*
   — rather than a loose collection of directly perceived facts.
2. ***Methodology.*** The methods of science are *systematic* and *generic*
   — rather than idiosyncratic and situation specific.
   Mathematics is a *tool* used by scientists for describing and analyzing ideas
   — rather than a source of factual knowledge.
   Mathematical modeling for problem solving involves *more*
   — than selecting mathematical formulas for number crunching.

3. ***Validity.*** Scientific knowledge is *approximate, tentative,* and *refutable*
   — rather than exact, absolute and final.

Cognitive Dimensions

4. ***Learnability.*** Science is *learnable by anyone* willing to make the effort
   — not just by a few talented people.
   Achievement depends more on *personal effort*
   — than on the influence of teacher or textbook.
5. ***Reflective thinking.*** For meaningful understanding of science, one needs to:
   - (a) concentrate more on the *systematic use of principles*
     — than on memorizing facts;
   - (b) examine situations in *many ways*
     — instead of following a single approach from an authoritative source;
   - (c) look for *discrepancies in one's own knowledge*
     — instead of just accumulating new information;
   - (d) *reconstruct* new subject knowledge in one's own way
     — instead of memorizing it as given.
6. ***Personal relevance.*** Science is *relevant to everyone's life;*
   — it is not of exclusive concern to scientists.
   Science should be studied more for *personal benefit*
   — than for fulfilling curriculum requirements.

Contrasting Alternatives Design (CAD)

To assess variability in student views in different disciplines, we constructed parallel paper-and-pencil forms of VASS for physics, chemistry and biology, as well as a VAMS form for mathematics. In 1995, each form consisted of 33 items, 16 of which comprised the scientific dimensions, and 17, the cognitive dimensions. Each VASS item is presented in the form of a statement followed by two contrasting alternatives which respondents are asked to balance on an eight-point scale (Figure 1). We devised this novel testing format called *Contrasting Alternatives Design* (CAD) (7), in order to overcome major validity and reliability problems encountered in traditional assessment formats (7 – 10).

RESULTS

This section offers a broad characterization of college and high school students' views about knowing and learning physics and the relation of these views to course

The first thing I do when solving a physics problem is:
(a) represent the situation with sketches and drawings.
(b) search for formulas that relate givens to unknowns.

Answer Options

① Only (a), Never (b); ② Mostly (a), Rarely (b); ③ More (a) Than (b); ④ Equally (a) & (b);
⑤ More (b) Than (a); ⑥ Mostly (b), Rarely (a); ⑦ Only (b), Never (a); ⑧ Neither (a) Nor (b)

FIGURE 1. A CAD item in VASS Form P11.

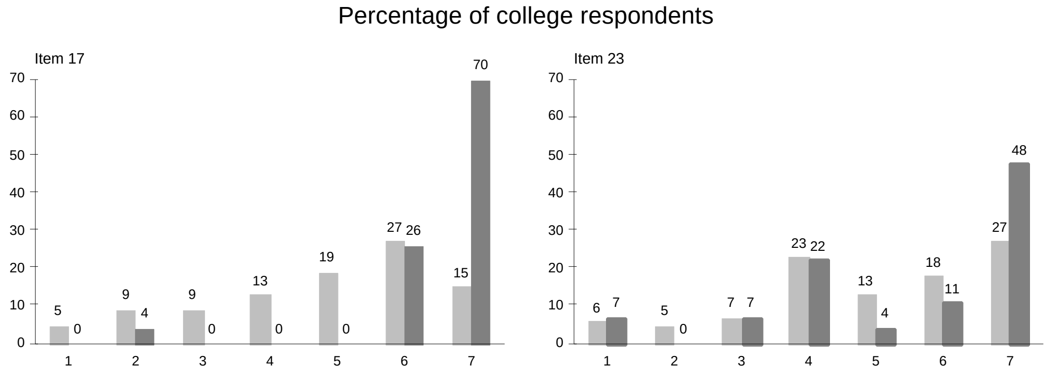
achievement. The discussion is based on results obtained in 1995 following the administration of VASS Form P11 as a pretest to 326 college students enrolled in various introductory physics courses, and to 2446 high school physics students.

Student and Teacher Views on Individual Items

VASS was given to college and high school teachers in order to: (a) establish baseline data for experts, and (b) compare students' views to their teachers'. Figure 2 illustrates typical differences between college student and professor responses on two items in VASS Form P11. Response distributions on all VASS items were similar for high school and college students, as well as for teachers and professors.

Figure 2 shows that options 6 and 7 in item 17 were chosen by 96% of college physics professors and 61% of college physics students. The contrast between teacher and student responses was even more pronounced on other items of the *cognitive dimensions* to which item 17 belongs. The responses of teachers and professors overwhelmingly indicated that they wanted their students to be *critical learners*. However, the responses of high school and college students indicated that less than one third were actually critical learners, while the rest were either *passive learners* or still confused as to which way they should go about studying physics.

Some contrast between professor and student responses was also apparent in item 23 (Figure 2). A much sharper contrast was detected in the other items of the *scientific dimensions* to which item 23 belongs. Teachers and professors expressed views that were overwhelmingly concurrent with *scientific realism*. Most students, however, either expressed views that were more aligned with *naive realism*, or had mixed views about the nature of science.



17. After the teacher solves a physics problem for which I got a wrong solution:
    (a) I discard my solution and learn the one presented by the teacher.
    (b) I try to figure out how the teacher's solution differs from mine.

23. Physicists say that electrons and protons exist in an atom because:
    (a) they have seen these particles in their actual form with some instruments.
    (b) they have made observations that can be explained by such particles.

FIGURE 2. Response distributions of participating college physics professors (dark, right bars) and students (light, left bars) on a *cognitive* item (No. 17) and a *scientific* item (No. 23) in VASS Form P11.

Student Profiles

In addition to analyzing students' positions on individual items, we looked for patterns in their responses on all VASS items, in order to: (a) identify general profiles in which student responses can be grouped distinctively, and (b) assess how these profiles relate to student performance in physics courses.

Item Response Classification

A careful exploratory analysis of teacher and student responses led us to the following considerations with regard to *individual items*:

1. Teacher answers were polarized toward one specific alternative in all items. In some items, all teachers and professors or the overwhelming majority of them chose exclusively this particular alternative (response option 1 or 7). In others, they were divided among the three options that favor this alternative over the other (options 1, 2, 3; or 5, 6, 7). A student is then considered to hold an *expert view* on a given item if her/his answer falls within the range of answers given by the majority of teachers/ professors.
2. Except on a few items, the few teachers/professors who were not polarized toward the expert alternative chose either response option 4 (equally both alternatives) or were divided between this option and the adjacent one (option 3 or 5). A student is then considered to hold a *mixed view* on a given item if s/he shares the middle position with those teachers/professors.
3. Following the above, a student is considered to hold a *folk view* on a given item if her/his answer is shared by virtually no teacher/professor, and is closer to the non-expert alternative.

For example, in items like item 17 (Figure 2), the *expert view* corresponds to options 6 and 7, the *mixed view*, to options 4 and 5, and *the folk view*, to options 1, 2, and 3. Had alternative (a) not been actually *false* in item 23, the expert view in this item would have corresponded to options 5, 6 and 7 as it actually did in other items with similar response distributions, and the mixed view to option 4, or to options 3 and 4. However, given the nature of the alternatives in item 23, the cutoffs between the three view types are the same in this item as in item 17.

Incidentally, item 23 was one of four VASS items where only about half the professors expressed the expert view. This reveals the subtlety of some issues addressed in VASS (or that even professors are not immune to misconceptions about the nature of physics knowledge!).

General Profile Classification

In order to have a simple and broad classification of student views, we grouped student responses over the entire VASS into four distinct profiles: *expert* (EP), *high transitional* (HTP), *low transitional* (LTP), and *folk* (FP).

The four profiles are distinguished by the *number* of views of a specific type, and are based on only 30 items in VASS Form P11. The remaining three items were discarded in the subsequent Form P12 that is currently being disseminated. The characteristics of the four profiles are presented in Table 1.

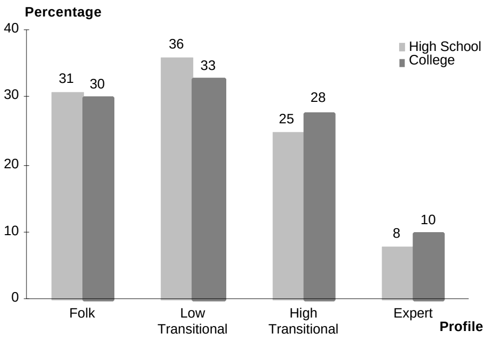
TABLE 1. General profile characteristics

Profile		**Number of Items out of 30**
Expert	EP	19 items or more with *expert* views
High Transitional	HTP	15 to 18 items with *expert* views
Low Transitional	LTP	11 to 14 items with *expert* views and at most the same number of items with *folk views*
Folk	FP	All others

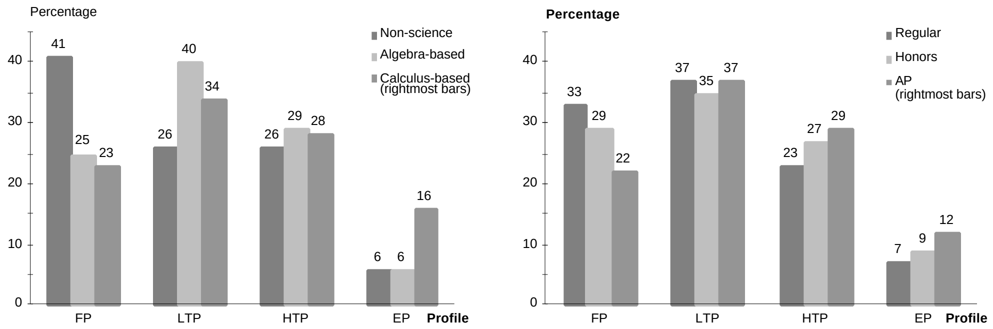
Student Profiles in Various Courses

Participating college students were enrolled in introductory physics courses of three different levels. 128 students (39%) were enrolled in a calculus-based course, 77 students (24%), in an algebra-based course, and the remaining 121 (37%), in two lower-level, elementary courses designed for non-science majors. Participating high school students were enrolled in physics courses of three different levels too. 1581 (65%) were enrolled in regular, algebra-based courses, 698 (29%) in honors, algebra-and-trigonometry-based courses, and 167 (7%) in AP, calculus-based courses. Figure 3 compares the profile distributions within and between the high school and college groups.

As can be seen in Figure 3, a minority of students in each group evinced an expert profile (EP), and roughly two thirds of all students fell in the FP and LTP



Overall profile distributions in college and high school



Profile distributions in college courses

Profile distributions in high school courses

FIGURE 3. Profile distributions in physics courses.

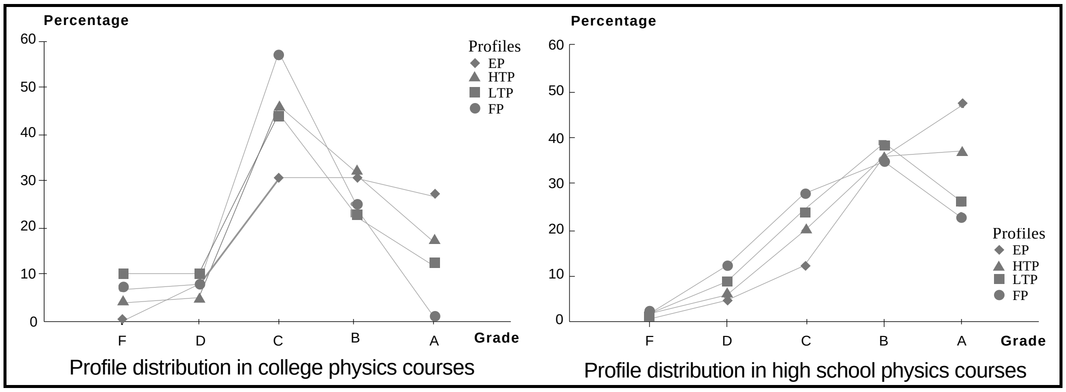
groups. No overall differences existed between the high school and college groups, but there were some within-group differences. The top diagram in Figure 3 suggests that the VASS profiles of physics students may already be well-established by the time they enter high school, and that subsequent physics instruction may have practically no effect on these profiles. The bottom diagrams in Figure 3 suggest that students in the more advanced physics courses are a little more polarized toward expert profiles, possibly because of the particular interests of these students more than anything else.

Student Views and Achievement

Educational researchers have often speculated that students' views about knowing and learning science affect their understanding of what they are taught in science courses (5, 6). In order to test this speculation, we assessed the relation between VASS profiles on the one hand, and final grades in physics courses and gains on the revised *Force Concept Inventory* (FCI) (11) on the other hand.

Figure 4 shows the distribution of student profiles across their final grades in physics. The proportion of college students who completed their courses with a grade of A or B was about 58% in the EP group, 49% in the HTP group, 35% in the LTP group, and 25% in the FP group. The proportion of high school students who completed their courses with the same grades A and B was 83%, 73%, 65% and 58% respectively in the four profile groups. There were virtually no A-students in the FP college group and no F-students in the EP college and high school groups.

Instruments like the FCI provide indices of understanding and achievement that are by far more objective and homogeneous than course grades. Figure 5 shows the profile distribution of high school students across their FCI gains. (The FCI was not administered to participating college students). The gain factor *g* is defined as the ratio of the actual pretest-posttest gain to the maximum possible gain. Hake (12) had shown that the average gain factor *g* is .23 in *traditional* courses where physics is taught by lecture and demonstration, and .52 in *interactive* courses where teams of students are constantly engaged in hands-on activities. The proportion of students that achieved *low gains* on the FCI ($g \leq .23$) increases gradually from about 12% in the EP group to about 46% in the FP group. The trend is reversed for *high gains* ($g \geq .52$): the proportion of students decreases gradually



Profile distribution in college physics courses

Profile distribution in high school physics courses

FIGURE 4. Distribution of student profiles across final grades.

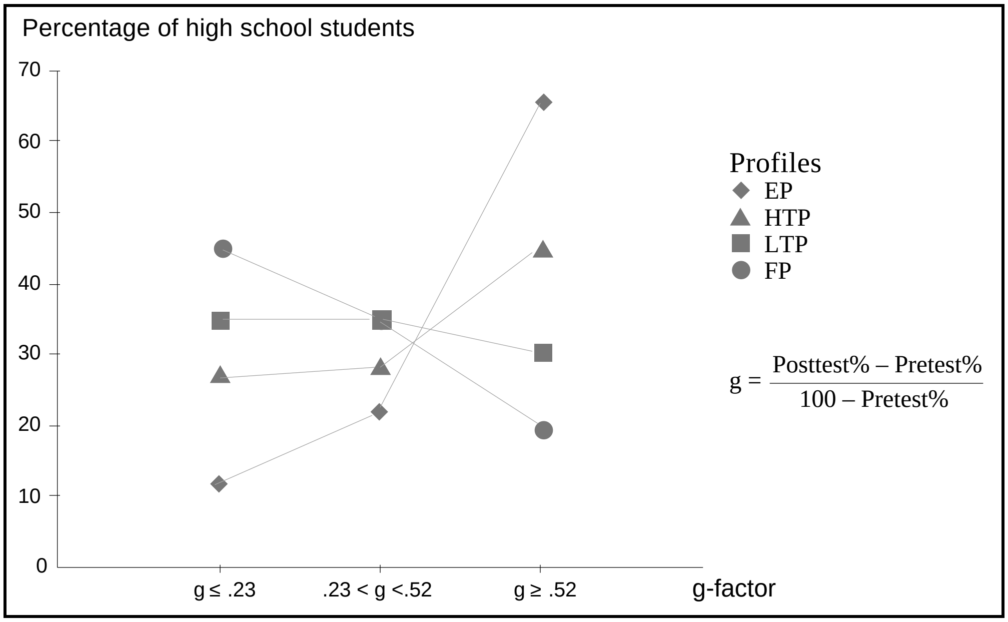


FIGURE 5. Distribution of student profiles across FCI gains.

from about 65% in the EP group to about 20% in the FP group. Data shown in Figure 5 pertain to students coming from traditional courses as well as interactive courses. Most of the latter follow *modeling instruction* (13). Of those with high FCI gains (g≥.52), only 5% of all students, and 3% of FP students came from traditional courses.

CONCLUSION

VASS shows that:

1. College and high school students hold views about knowing and learning physics that can be classified in three types: *expert*, *mixed*, and *folk*. In the scientific dimensions of VASS, expert views are typical of *scientific realism*, while folk views are reminiscent of *positivism* or *naive realism*. In the cognitive dimensions, expert views characterize *critical learning*, while folk views characterize *passive learning*.

2. *Students do not show a consistent tendency* towards one type of view or another on all VASS items. Every student holds a mixture of folk, mixed and expert views in any VASS dimension.

3. Student views on the entire VASS can be grouped into four distinct profiles: *expert, high transitional, low transitional,* and *folk*.

4. *The profile distributions are similar in college and high school.* No more than 10% of all students exhibit an expert profile, and the remaining students are almost evenly distributed among the other three profiles.

5. *Student profiles correlate significantly with physics achievement.* Students with an expert profile are the most likely to have the highest achievement in their physics courses. Students with a folk profile are the most likely to have the

lowest achievement. Students with transitional profiles are the most likely to fall in the middle.

What is reported in this paper represents only a small sample of VASS features and outcomes. In order to learn more about the development of VASS and its outcomes in physics, as well as in biology, chemistry and mathematics, interested readers are invited to refer to our related publications (7, 14), and to watch for upcoming articles in major science and mathematics education journals.

Our work with VASS is by no means exhausted. Data are still being analyzed in many respects. Profiles reported in this paper may still be refined based on incoming data from many colleges and high schools. New VASS forms may be developed along new dimensions. All this will be used in the development of new curricula at all levels.

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