AC 2008-1034: FROM PIE TO APPLES: THE EVOLUTION OF A SURVEY INSTRUMENT TO EXPLORE ENGINEERING STUDENT PATHWAYS

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Abstract

The Academic Pathways Study (APS) of the Center for the Advancement of Engineering Education (CAEE) is a cross-university study that systematically examines how engineering students navigate their education, and how engineering skills and identity develop during the undergraduate period. Through the collective work of the APS, two instruments have emerged – the Persistence in Engineering (PIE) survey and the Academic Pathways of People Learning Engineering Survey (APPLES). This paper describes the redesign of the longitudinal PIE survey instrument for the cross-sectional administrations of APPLES as informed by emerging findings from other APS methods. We discuss the challenges of the evolution of PIE and APPLES while addressing the comparability of these instruments to each other, and outline plans for future APPLES deployments and analyses.

Introduction/Background

The Academic Pathways Study (APS) of the NSF-funded Center for the Advancement of Engineering Education (CAEE) is a cross-university study that systematically examines how engineering students navigate their education, and how engineering skills and identity develop during their undergraduate careers[1,2]. APS research falls under the umbrella of the Center for the Advancement of Engineering Education (CAEE) whose goals are to:

1. Identify ways to boost the numbers of students who complete engineering degrees (including increasing the numbers of women and traditionally underrepresented groups)
2. Better support those enrolled in engineering programs
3. Encourage greater numbers of students who complete engineering degrees to enter engineering professions

APS addresses the following fundamental research questions:

- **SKILLS**: How do students' engineering skills and knowledge develop and/or change over time? How do the technological and mathematical fluencies of engineering students compare with those found in professional engineering settings?
- **IDENTITY**: How do these students come to identify themselves as engineers? How do students' appreciation, confidence, and commitment to engineering change as they navigate their education? How does this in turn affect how these students make decisions about further participation in engineering after graduation?
- **EDUCATION**: What elements of students' engineering education contribute to the changes observed in questions one and two? What do students find difficult and how do they deal with the difficulties they face?

- **WORKPLACE**: What skills do early-career engineers need as they enter the workplace? Where did they obtain these skills? Are there any missing skills? How are people's identities transformed in moving from school to work?

The APS has utilized a variety of methods including surveys, structured interviews, ethnographic methods, engineering design tasks, and academic transcripts to gain a broader and richer picture of students' undergraduate engineering experiences. Of this portfolio of methods, a key component has been the survey and through the collective work of the APS, two instruments have emerged – the Persistence in Engineering (PIE) survey and the Academic Pathways of People Learning Engineering Survey (APPLES).

The Persistence in Engineering (PIE) survey was designed to identify and characterize the fundamental factors that influence students' intentions to pursue an engineering degree over the course of their undergraduate career and upon graduation, to practice engineering as a profession[3, 4]. First administered in Winter 2003, the PIE survey was deployed seven times from 2003-2007 to approximately 160 students at four institutions ("Longitudinal Cohort").

Building upon the PIE survey and the findings from the other APS methods, the Academic Pathways of People Learning Engineering Survey (APPLES) was designed to look at academic and professional persistence in two different cross-sectional populations of American undergraduate engineering students[5]. The main objective of APPLES was to corroborate earlier findings from the APS on a larger scale and in particular, to explore the generalizability of findings from the PIE survey to engineering students at American higher education institutions.

The first administration of APPLES ("APPLES1") was conducted in April 2007 and was focused on the broader population of students at the same four core institutions who participated in the earlier APS research (the "Broader Core Sample"). These students had not previously taken the PIE survey and represented a second sample of students from these institutions, comparable to the Longitudinal Cohort. Students who were studying engineering, interested in studying engineering, or those who thought they would study engineering but opted for a non-engineering major were invited to complete the survey. They were recruited using posters, ads in the student newspaper, email invitations from the school of engineering, student engineering societies, and departments, and announcements made in relevant courses [6]. Over 900 students completed the APPLES1 survey.

The second administration of APPLES ("APPLES2") was conducted from January to March 2008 with a carefully selected, stratified sample of 21 universities in the U.S. (the "Broader National Sample"). Although the targeted population of the Broader National Sample is American undergraduate engineering students, it was not feasible to randomly sample individual students. Instead, sampling was done by institution using a stratified approach based on institutional characteristics

Once the institutions were selected, the student population at each school was divided into subpopulations (or strata) for recruitment (see Donaldson & Sheppard (2008)[7] for a detailed description of the APPLES2 sampling plan). The individualized stratification of students at each institution improved the representativeness of the overall sample by ensuring the inclusion of responses from underrepresented sub-populations and reducing overall sampling error. To maintain a balanced sample of engineering students and institutions, the APPLES Broader National Sample was stratified by the following institutional characteristics, in order of importance:

1. Carnegie 2000 classification
2. Ethnicity, gender and enrollment status (full-time versus part-time)
3. Institution size, type of institution (private versus public), geographic location, and whether it has a religious affiliation

Comparability of the PIE and APPLE Survey Instruments

In an ideal world, we would have been able to simply administer the PIE survey instrument to both the Broader Core School Sample and the Broader National Sample. However, whereas the students in the Longitudinal Cohort were paid $175 annually to fill out the PIE surveys and participate in other data collection activities supporting the APS, the APPLES respondents were compensated with $4 to complete the survey. Modification of the PIE instrument for a cross-sectional population was also necessary, both in terms of survey language as well as survey length.

This obvious contrast in both time commitment and monetary incentive spurred the redesign and streamlining of the PIE instrument (which took students from 20 to 40 minutes to complete) into a leaner survey that could be completed in approximately 10 minutes. The process of refining the PIE instrument took several iterations with both internal and external piloting and many challenging discussions about which items and variables to keep and which to eliminate.

At their core, the PIE and APPLES instruments share a common set of variables representing the key concepts that researchers have suggested influence undergraduates' persistence in the engineering major. Table 1 below organizes the core variables according to the relevant APS research question category and identifies whether the variable was addressed in one, two, or all three of the APS survey instruments, thereby providing some sense of the evolution of individual variables over the course of the study.

Table 1. Mapping of core variables across APS survey instruments organized by relevant APS research question category.

APS Research Question Category	APS Survey Instrument		
	PIE Survey	*APPLES1*	*APPLES2*
SKILLS	Confidence in Math and Science Skills		
	Confidence in Professional and Interpersonal Skills		
	Confidence in Solving Open-Ended Problems		
	Perceived Importance of Math and Science Skills		
	Perceived Importance of Professional and Interpersonal Skills		
	Confidence in Math and Science Skills		
IDENTITY	Motivation (Financial)		
	Motivation (Family Influence)		
	Motivation (Social Good)		
	Motivation (Mentor Influence)		
	Extracurricular Fulfillment		
	---	---	Intrinsic Motivation (Psychological)
	---	---	Intrinsic Motivation (Behavioral)
EDUCATION	Academic Persistence*		
	Curriculum Overload		
	Financial Difficulties*		
	Academic Disengagement (Liberal Arts Courses)		
	Academic Disengagement (Engineering)		
	Frequency of Interaction with Instructors		
	Satisfaction with Instructors		
	Overall Satisfaction with Collegiate Experience*		
	Exposure to Project-Based Learning Methods (Group & Individual Projects) *	---	Exposure to Project-Based Learning Methods (Group & Individual Projects) *
	Collaborative Work Style	---	**---**
	Satisfaction with Academic Facilities	---	**---**
WORKPLACE	Professional Persistence*		
	Knowledge of the Engineering Profession*		

* indicates a variable defined by a single item

From PIE to APPLES1

We created the APPLES1 instrument using the PIE survey as a foundation. However, we wanted to compare our findings obtained from students at our four core institutions (who took the PIE survey each year for four years) with a broader sample from those same institutions as well as nationally (the populations targeted by the APPLES survey). Cutting the PIE survey in half jeopardized our ability to compare the data from the PIE and APPLES surveys, since we inevitably would have had to eliminate a variety of items and variables. One major consideration in the design of APPLES was to reduce the length of the survey while still meeting our research objective of testing the generalizability of preliminary results from the PIE survey. .

Three factors guided the modifications and streamlining from the PIE survey to APPLES. The first involved checking the language of the questions, given that the targeted audience for the survey had now broadened. Whereas the respondents for the PIE survey were primarily students who had decided to major in engineering, the APPLES instrument also needed to make sense to non-persisters – students who at some point during their undergraduate career had expressed an interest in engineering but had decided (or were in the process of deciding) not to major in engineering. Also, as a cross-sectional survey, the language of APPLES1 had to be appropriate for capturing a snapshot of students' attitudes and thoughts at one point in time, and not twice a year as with the Longitudinal Cohort. These students in the Broader Core School Sample and the Broader National Sample were no longer limited to one academic class but included freshmen, sophomores, juniors, seniors (traditional and those 5+ years), as well as transfer and part-time students.

The second set of changes focused on identifying which variables should be kept and eliminated. Table 2 describes a subset of APPLES1 variables and their constituent items, along with the Cronbach's alpha scores for both the APPLES1 Spring 2007 and the PIE Fall 2005 administrations (single item variables were not included here since multiple items are needed in order to calculate the alpha score). The Cronbach's alpha is a test of internal consistency and represents the extent to which the items in a scale can be treated as measuring the same latent construct (such as motivation). Although generally speaking, Cronbach's alphas of .6 and higher are considered acceptable levels of internal consistency, this threshold is arbitrary and an alpha value of .7 or above is preferable. The PIE Fall 2005 alpha or scale reliability coefficient presented in Table 2 is based on responses from only the sophomores in the Longitudinal Cohort. The consistency between the two alpha scores in Table 2 demonstrates the reliability of these variable measures when administered to different student populations.

Table 2: Selected APPLES1 Survey Variables, Items, and Internal Consistency Reliabilities, Spring 2007

Selected APPLES1 Variables and Constituent Items	**APPLES1 Spring 2007 Alpha**	**PIE Fall 2005 Alpha**
1. Motivation (Financial) *Engineers are well paid.* *Engineers make more money than most other professionals.* *An engineering degree will guarantee me a job when I graduate.*	**.82**	**.76**
2. Motivation (Family Influence) *My parents would disapprove if I chose a major other than engineering.* *My parents want me to be an engineer.*	**.87**	**.85**

Selected APPLES1 Variables and Constituent Items	APPLES1 Spring 2007 Alpha	PIE Fall 2005 Alpha
3. Motivation (Social Good) *Technology plays an important role in solving society's problems.* *Engineers have contributed greatly to fixing problems in the world.*	**.64**	**.70**
4. Motivation (Mentor Influence) *A faculty member, academic advisor, teaching assistant or other university affiliated person has encouraged and/or inspired me to study engineering.* *A non-university affiliated mentor has encouraged and/or inspired me to study engineering.*	**.60**	**.65**
5. Confidence in Math and Science Skills *Science ability* *Math ability* *Ability to apply math and science principles in solving real world problems*	**.82**	**.83**
6. Confidence in Professional and Interpersonal Skills *Leadership ability* *Self confidence (social)* *Public speaking ability* *Communication skills* *Ability to perform in teams* *Business ability*	**.80**	**.84**
7. Confidence in Solving Open-ended Problems *I am skilled at solving problems with multiple solutions.* *Confidence: Critical thinking skills* *Creative thinking is one of my strengths.*	**.68**	**.69**
8. Perceived Importance of Math and Science Skills *Math ability* *Science ability* *Ability to apply math and science principles in solving real world problems*	**.79**	**.79**
9. Perceived Importance of Professional and Interpersonal Skills *Leadership ability* *Public speaking ability* *Self confidence (social)* *Communication skills* *Ability to perform in teams* *Business ability*	**.83**	**.79**

Selected APPLES1 Variables and Constituent Items	APPLES1 Spring 2007 Alpha	PIE Fall 2005 Alpha
10. Extracurricular Fulfillment (Non-engineering) *Some people desire to be involved in non-engineering activities on or off campus, such as hobbies, civic or church organizations, campus publications, student government, social fraternity or sorority, sports, etc. How important is it for you to be involved in these kinds of activities?* *How often are you involved in the kinds of activities described above?*	**.82**	**.85**
11. Curriculum Overload *How stressed do you feel in your coursework right now?* *During the current year, how much pressure have you felt with course load (amount of course material being covered)* *During the current year, how much pressure have you felt with course pace (the pace at which the course material is being covered)* *During the current year, how much pressure have you felt with balance between social and academic life* *How well are you meeting the workload demands of your coursework?*	**.78**	**.81**
12. Academic Disengagement (Liberal Arts Courses) *Skipped non-engineering related class* *Turned in non-engineering related assignments late* *Came late to non-engineering related class* *Turned in non-engineering related assignments that did not reflect your best work*	**.88**	**.58**
13. Academic Disengagement (Engineering Related) *Skipped engineering related class* *Turned in engineering related assignments late* *Turned in engineering related assignments that did not reflect your best work* *Came late to engineering related class*	**.86**	**.70**
14. Frequency of Interaction with Instructors *Instructors during class* *Instructors during office hours* *Instructors outside of class or office hours*	**.74**	**.69**
15. Satisfaction with Instructors *Availability* *Quality of instruction* *Quality of advising by instructors*	**.72**	**.84**

Lastly, we considered the emerging findings from the other APS data collection methods in order to identify additional factors about the undergraduate engineering experience that would influence persistence. Qualitative analyses of the ethnographic interviews conducted by Lichtenstein (2007)[8] suggested a potential relationship between the strength of students' intention to major in engineering as freshmen and their actual commitment to the major. Three items were developed to assess students' level of commitment to majoring in engineering when they entered the institution and explore the factors that either caused doubt about majoring or confirmation of their decision to continue with an engineering major. The data collected from these questions in APPLES1 showed a pattern of results in which students' decision-making about their major appears to be much more fluid than what one might have assumed. Although the results of these analyses are ongoing, the integration of findings from both quantitative and qualitative APS methods represents a valuable contribution and perhaps a useful model for future research.

From APPLES1 to APPLES2

One of the first steps in refining the APPLES1 instrument for deployment to the national sample of 21 American institutions was to ensure that the demographic questions were appropriate and detailed enough to capture the diversity in institutions and student respondents. The survey changes made during the transition from APPLES1 to APPLES2 were minimal due to the constraint of wanting to maintain comparability of APPLES2 with both the PIE and APPLES1 instruments. The changes that were made in APPLES2 were focused on bolstering several scales with low internal reliability. In the example below, we tested a new item in our external pilot which suggested that the alpha score would be increased to .89 if all three items were included. Although this finding is based on a pilot sample of 38 students from four institutions similar to our target institutions, we decided to add this item to APPLES2 while also keeping the original items that comprised the Motivation (Mentor Influence) construct.

	APPLES1 Spring 2007 Alpha	**PIE Fall 2005 Alpha**
Motivation (Mentor Influence)	**.60**	**.65**
A faculty member, academic advisor, teaching assistant or other university affiliated person has encouraged and/or inspired me to study engineering.		
A non-university affiliated mentor has encouraged and/or inspired me to study engineering.		
NEW: A mentor has introduced me to people and opportunities in engineering.	w/all 3 items = .89	

After reviewing student responses to an open-ended question on APPLES1 asking "Is there anything you want to tell us about your experiences in engineering that we haven't already asked you about?" we added new items addressing the psychological and behavioral perspectives of intrinsic motivation. The intrinsic motivation (psychological) construct is based on the Situation Motivation Scale developed by (Guay, Vallerand, and Blanchard, 2000)[9].

	Fall 2007 External Pilot
Intrinsic motivation (Psychological)	**.89**
I think engineering is fun.	
I think engineering is interesting.	
I feel good when I am doing engineering.	
Intrinsic motivation (Behavioral)	**.84**
I like to figure out how things work.	
I like to build stuff.	
Finding solutions to technical problems gives me a sense of satisfaction	

One of the incentives for institutions to participate in the APPLES research study was the individualized campus report summarizing their students' responses. As a result, the selection of questions for the APPLES instrument was also influenced by the interests of the anticipated audience for APPLES findings – deans, department chairs and faculty involved in ABET accreditation efforts, etc. – and thinking about how these research findings might be interpreted and put into practice.

Scale reliability and validity: Cronbach's alpha analyses were conducted to calculate the reliability associated with how well a set of items measure a single theoretical construct. The variables in the PIE instrument had largely been refined through multiple administrations although several of the variables were excluded due to concerns about external validity and reliability due to low alpha scores. The similar alpha coefficients from APPLES1 with PIE reinforced our confidence in the selection of variables for APPLES2 and their generalizability to other student populations and institutional cultures outside of the core schools represented by the Longitudinal Cohort and Broader Core Schools Sample.

Evidence of viability: Inclusion of variables in the APPLES instruments were based on preliminary analyses from the longitudinal analysis of PIE data and pilot testing. Our research team solicited contributions based on emerging findings from the other APS data collection methods (structured and unstructured interviews, engineering tasks) where available such that the final instruments are representative of the collective work of the APS as a whole and not just the survey method.

Interest to target audiences: Whereas the audience for the findings from the PIE surveys was primarily the engineering education and research communities, the institutional results from APPLES are to be shared with the dean of engineering at each of the participating schools. As a result, the practical implications for the selection of variables also needed to be taken into consideration.

Length of the survey: Our target completion time for APPLES was approximately 10 minutes since we knew if the survey was longer, fewer students would complete it, therefore reducing both sample size and statistical reliability. Using student comments from our external piloting of the survey, clarifications in question wording and formatting were made in order to increase speed and readability. We struggled with keeping the survey a reasonable length for a $4 incentive while maintaining the integrity of the survey as an insightful and valuable data collection method. We found (internal and external) piloting of the survey questions to be essential steps, both for checking the overall time to complete the survey online as well as the choice of items to include. In addition, we were able to program features in our survey tool to capture an estimated completion time for each potential survey item to guide our decisions about items.

Conclusion

In summary, the evolution of PIE to APPLES1 to APPLES2 was guided by the need for comparability of findings while ensuring the integrity of each individual survey. The decisions about which PIE variables to include or exclude in the APPLES instruments were made according to methodological, institutional, and practical constraints. In the future, we plan to expand our data collection to include students at institutions outside the United States in order to broaden our exploration of the correlates of engineering persistence in the global context.

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