

# Scaling Up: Taking the Academic Pathways of People Learning Engineering Survey (APPLES) National

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**Abstract** - The Academic Pathways of People Learning Engineering Survey (APPLES) was deployed for a second time in Spring 2008 to undergraduate engineering students at 21 American universities. The goal of APPLES was to corroborate and extend findings from the Academic Pathways Study and the first deployment of APPLES (Spring 2007) on factors that correlate with persistence in engineering on a national scale. This set of deployments, which surveyed over 4,500 students, was among the largest and broadest cross-sectional surveys focusing on undergraduate engineering ever undertaken.

Because there was no readily-available list of undergraduate students attending American institutions studying and intending to study engineering, we sampled by institution using institutional characteristics such as Carnegie 2000 classification. In seeking participation by a broad range of institutions, we recognized the need to vary the target student strata for recruitment by institution. In this process paper, we present an overview of our institutional sampling, discuss our student sampling and recruitment, and report response results. We extend our lessons learned from deploying the online survey at four institutions to 21 institutions, including coordination with local campus coordinators, IRB requirements, subject recruitment and deployment to build on the model for conducting survey design and research for engineering education researchers.

*Index Terms* - Cross-sectional study, Engineering persistence, Recruitment, Survey methodology.

## OVERVIEW & BACKGROUND

The goal of the second set of Academic Pathways of People Learning Engineering Survey (APPLES or APPLE survey) deployments is to corroborate and extend the data from the Academic Pathway Study (APS) on a national level. The APS seeks to explore key questions around skills, identity development, and factors that relate to student persistence in engineering. The APS data include two survey instruments developed to study questions around persistence: the Persistence in Engineering (PIE) survey (deployed seven times over four years with a longitudinal cohort of 160 students at four institutions starting in 2003), and APPLES [1-4].

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APPLES was first deployed (“APPLES1”) in Spring 2007 and surveyed the broader undergraduate engineering population at the four core APS institutions [5]. The second APPLES administration (“APPLES2”), the focus of this paper, surveyed undergraduate students at 21 universities in the United States<sup>1</sup>. The APPLES instrument is derived from the PIE survey instrument. The APPLES2 instrument is nearly identical to the APPLES1 instrument; the major changes being the addition of items for two new and several existing variables, and basic improvements for readability (see [1] for more details).

Due to our focus on persistence in engineering education, we recruited three groups of undergraduate students to take APPLES: (1) *engineering students*: those who declared an engineering major or had already committed to engineering programs; (2) *pre-engineering students*: those who intended to declare an engineering major; and (3) *non-persister students*: those who were initially interested in majoring in engineering, but decided to pursue a non-engineering major.

The APPLES survey was administered online and took approximately 10 minutes to complete. Respondents were offered an incentive of \$4 paid to them through an online financial transaction company<sup>2</sup>. Confidentiality of student identities was maintained by separate databases where the email addresses submitted by students to claim the incentive were not linked to the individual survey responses. All aspects of the APPLES2 deployments except recruitment, were managed by the APPLES team based at Stanford University.

While there is significant literature on survey development in general<sup>3</sup>, there is little literature on survey methodology for engineering education research. We have written about the practical aspects of our APPLES1 experiences and lessons learned, particularly related to recruiting undergraduate engineering students for an online survey [5]. We also documented the specific details and steps behind the design of our survey instruments with recommendations for researchers

<sup>1</sup> APPLES institutions’ identities are deliberately kept confidential due to the sensitivity of some of the data collected.

<sup>2</sup> See [5] for more information on the APPLES’s incentive and other options considered.

<sup>3</sup> See, for example, Salant and Dillman [6].

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wishing to engage in similar survey efforts [1]. Besterfield-Sacre and Atman [7] outline their development process of the Pittsburgh Freshman Engineering Attitudes Survey instrument, focusing on item-level refinement based on piloting.

### SAMPLING PLAN

Because the goal of APPLES2 was to corroborate and to extend the APS data to a nationally-representative sample, the study population was undergraduate engineering students at American institutions. However, with no readily-available list of U.S. undergraduate engineering students to randomly sample, we sampled by institution.

We limited our scope to four-year institutions with at least one ABET-accredited undergraduate engineering program in 2004<sup>4</sup>. We chose to restrict our population in this way because our investigation of four-year American institutions offering undergraduate engineering studies revealed different figures depending on the source. According to the College Board's 2004 records [10], there were 563 institutions, while the ASEE [8] listed 319. The difference between the College Board 563 and the ASEE 319 (244 institutions) was predominantly accounted for by "3+2" institutions – mostly small liberal arts colleges offering three years of pre-engineering study before a student transfers to another (typically larger) institution for two years to complete his/her engineering degree. At the end of the five years, the student graduates with bachelors degrees from both institutions. Whereas the two-year engineering "completion" program is ABET-accredited, the three-year programs are not. While the number of 3+2 institutions is fairly high, we estimated based on available literature the number of engineering students graduating from these programs to be relatively low.

#### I. Stratification of Institutions

Stratification, defined as the process of determining respondent characteristics, drove the determination of APPLES's institutional sample size and the recruitment of specific institutions. To ensure a balanced national sample of engineering students and institutions, we stratified using several institutional characteristics, in order of importance:

1. Carnegie 2000 classification
2. Student body ethnic composition, gender balance, and enrollment status (full-time versus part-time)
3. Institution size, type (private versus public), geographic location, whether it had a religious affiliation, and number of transfer students

<sup>4</sup> We used 2004 data because the APPLES sampling plan was completed in March 2006, and at that time, 2005 data was incomplete. We do not believe the institutional data have significantly changed since 2004 to present, but should note that undergraduate engineering enrollments were relatively high in 2004 with 402,627 students in the U.S. [8]. In 2006, there were 373,074 students [9].

#### II. Sampling Institutions

The calculated respondent sample size drove the institutional sample size and was, in turn, based on data from the PIE survey<sup>5</sup>. Using a power calculation, we had estimated a minimum sample size of 400 subjects for APPLES1 [2]. Since APPLES2 was to be representative of undergraduate engineering students in the U.S., its sample required 400 "like" Carnegie 2000 subjects (from *Doctoral/Research – Extensive* and *Specialized Institution – Engineering* institutions) plus a representative sample of students from "other" institutions (*Baccalaureate College – Liberal Arts*, *Baccalaureate College – General*, *Specialized Institution – Other*, *Masters Colleges and Universities 1*, and *Doctoral Research – Intensive*). After determining the required number of institutions by Carnegie type, we added four more institutions based on the secondary and tertiary factors, (e.g. a Hispanic-serving institution, large part-time enrollment) and institutional characteristics (e.g. private university, geographic location, high 3+2 transfer population). Building in additional redundancy, we estimated that we would need 21-25 institutions with at least 1,080 total participants<sup>6</sup>. The "required" column of Table I shows the number and types of institutions indicated by our sampling plan to achieve a nationally-representative sample of undergraduate engineering students in the United States.

Type of institution	Required	Participated
<b>Primary Stratifications</b>		
Doctoral/Research – Extensive	5	7
Doctoral/Research – Intensive	2	4
Specialized Institutions – Engineering	2	3
Master's Colleges and Universities I	2	3
Specialized Institutions – Other	1	0
Baccalaureate Colleges – General	1	2
Baccalaureate Colleges – Liberal Arts	1	2
<b>Secondary Stratifications</b>		
Historically Black Colleges and Universities	1	2
Hispanic-Serving Institutions	1	2
Single-Gender Institutions	1	1
Part-Time Student Population > 30%	1	4
<b>Recruiting redundancy</b>	3-7*	3
<b>TOTAL</b>	<b>21-25</b>	<b>21</b>

\*We estimated we needed to recruit 3-7 additional institutions should one or more institutions be unable to participate in APPLES late in the process.

<sup>5</sup> For more information, see [5].

<sup>6</sup> See [2] for sampling details including assumptions, calculations and general information.

Tertiary Stratification Considerations	National Picture (2007)*	Participated
Institution size (based on enrollments)	Large = 54% Medium = 43% Small = 3%	Large = 33% (7) Medium = 38% (8) Small = 29% (6)
Geographic diversity		17 states represented
Funding type	Public = 63% Private = 37%	Public = 67% (14) Private = 33% (7)
Religious affiliation	14% of institutions 4% of population	5% (1 institution)
Transfer student population	(Information not available)	Two 3+2 completion institutions

\*Percentage of national sample of 319 institutions [8].

### SELECTING INSTITUTIONS

Institutions were invited to participate in APPLS based on “strategic sampling”. We ranked the U.S. institutions with at least one ABET-accredited engineering major using their primary and secondary characteristics. An institution was then selected based on these characteristics and with some consideration as to whether a member of our research team had personal contacts there<sup>7</sup>. The process was iterative in that with each selection, the desirable institutional characteristics changed and the ranking of institutions was updated for the next selection. Tertiary institutional characteristics were used to decide between institutions of close rank.

We invited 25 institutions to take part in APPLS (see Table I). Our approach was to build in redundancy for strata with only one institution. For example, only one *Baccalaureate Colleges – General* institution was required by our sampling plan, but we invited two. We also felt it necessary to err on the conservative side with recruitment should an institution withdraw from APPLS late in the process.

Institutional recruitment was initiated in mid-2007 with invitation letters sent to each institution's dean and a special session held at the American Society of Engineering Education annual conference. As an incentive to participate in the study, the APPLS2 institutions would each receive a complimentary report highlighting their institutional data relative to the rest of the APPLS2 cohort. Twenty-one institutions ultimately accepted the invitation to participate – a large majority very enthusiastically. We were unable to secure the participation of a military academy (Carnegie 2000 classification *Specialized Institutions – Other*), despite approaching three. Tables I and II show APPLS institutions' characteristics relative to required and desired institutional sampling attributes.

<sup>7</sup> Institutions with personal contacts were desirable because we felt this may assist the likelihood of an institution's participation in APPLS. Our team had no contacts at 15 of the 21 APPLS institutions.

We asked each participating campus to appoint a local coordinator to assist us in understanding the local institutional culture, provide updated institutional data, and plan and implement campus-specific recruitment. The most successful coordinators were teams comprised of an actively-involved senior administrator (such as an assistant dean) and a more junior non-tenure track partner, such as a researcher.

We planned APPLS2 deployments to last five days (Monday through Friday) based on the response patterns of students who participated in APPLS1. With APPLS1, we found that response was high immediately after students received an announcement or saw a poster, but then tapered off significantly with time, especially over weekends [5]. Institutions were offered three deployment weeks to choose from, ranging from late January to late February 2008. A fourth deployment was added in March 2008 for two institutions unable to participate in the earlier deployments.

#### I. Institutional Review Board (IRB) Process

IRB human subjects approval was required only for APPLS2 institutions with APS researchers (there were two). We designed the survey and its implementation in such a manner as to secure an umbrella IRB approval for all participating students and institutions through Stanford University. An additional four institutions voluntarily obtained local IRB approval with support from our team.

#### II. Student strata and strata targets for recruitment

To ensure a diversity of students from each of the participating APPLS institutions, including the over-sampling of specific student groups, we defined student strata groups at each institution based on our research goals and grouped them by importance:

- *Primary strata*: academic level (freshmen, sophomores, juniors, and seniors), persisters/non-persisters, and men/women
- *Secondary strata*: ethnic minority<sup>8</sup> and international<sup>9</sup> students
- *Tertiary strata*: part-time and transfer students

<sup>8</sup> We defined ethnic minority students as those traditionally underrepresented in American undergraduate engineering programs relative to their representation in the general population: African American, Latino/a and Native American [11, 12].

<sup>9</sup> We defined international students as those that do not hold U.S. citizenship.

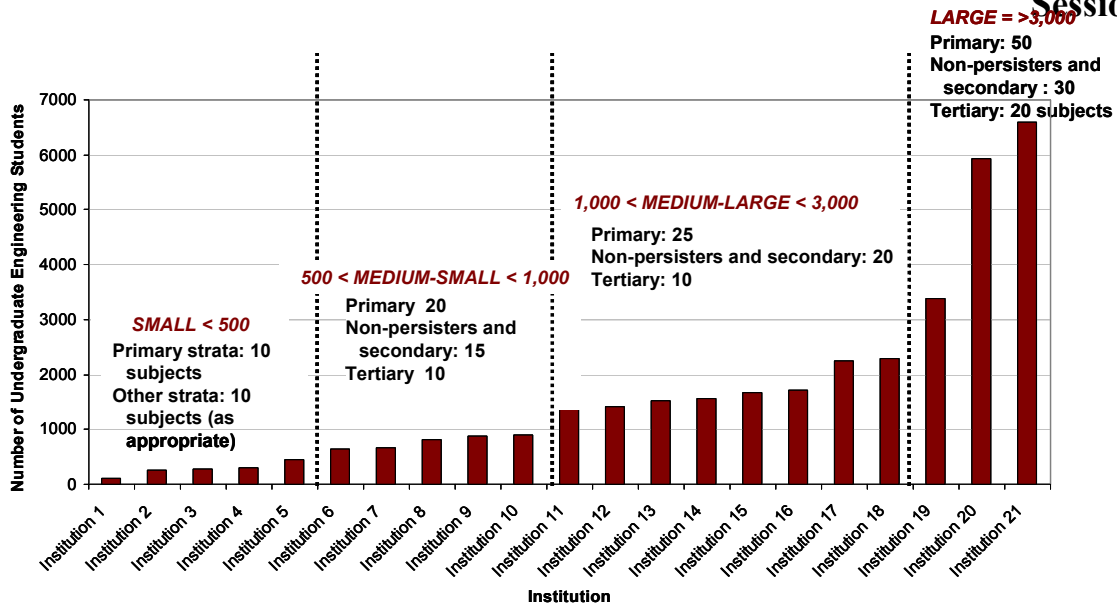


FIGURE I  
BINNING OF APPLES2 INSTITUTIONAL COHORT BY UNDERGRADUATE ENROLLMENT TO DETERMINE STRATA TARGETS FOR SUBJECT RECRUITMENT

During the survey deployments, we tracked each institution's strata responses daily and sent individualized reports to the local coordinators so they could adjust their recruitment strategies as needed in real time.

Strata targets for recruitment were based on the undergraduate engineering enrollment at each institution. As shown in Figure I, institutions were visually binned into four groups by their undergraduate engineering enrollments, *small* (<500 students), *medium-small* (500-1,000 students), *medium-large* (1,000-3,000 students), and *large* (>3,000 students). The institution's bin determined its strata targets (see Figure I). The strata targets for a medium-small institution, for example, would be 20 subjects for each of the primary student strata except non-persisters (freshmen, sophomores, juniors, seniors, men and women), 15 subjects each for non-persisters and secondary strata (ethnic minority and international students), and 10 subjects each for tertiary strata (transfer and part-time students). These targets were then adjusted as needed in conversation with local coordinators. For example, a small technical institution did not have 10 international students and several private institutions did not have part-time students. In these cases, the specific strata (and targets) were eliminated.

In establishing the targets, we sought to balance the minimum sample size required for sound statistical analysis with recruitment costs at the institutions (e.g. local coordinator time and total incentive payout). Our student response rate from the APPLES1 deployment was 17 percent, and based on the National Survey of Student Engagement (NSSE), we knew that we could expect up to a 30 percent response rate [13] (higher is possible, but difficult). At institutions with very low undergraduate engineering enrollments (<200 students),

achieving ten subjects per primary stratum<sup>10</sup> would require recruiting over 30 percent of their undergraduate engineering student body, whereas at large institutions (>3,000 students), too many participants would not add significant insights relative to the incentive costs and additional time and resources required for both recruitment and data analysis.

### III. Piloting

The APPLE2 survey underwent one round of piloting with 52 undergraduate engineering students at three institutions not participating in APPLES (and not affiliated with APS). Because the APPLES2 instrument was very similar to the APPLES1 instrument, we used the piloting primarily to test new variables addressing students' motivations to study engineering. We also piloted several new items introduced to strengthen several existing variables. Since we knew APPLES2 was to be administered to a broader and more diverse audience than APPLES1, we were also very interested in student comments regarding the applicability and clarity of question content and phrasing. Based on the piloting results, we included the new motivation variables and additional items, as well as streamlined the survey as a whole.

### IV. Participant Recruitment

The main participant recruitment method was an email sent from a senior administrator (such as a dean) to undergraduate engineering students at the institution. Recruitment also included posters and, for a small number of institutions, directed advertisements on a popular social networking website.

<sup>10</sup> We used 10 subjects as the minimum number of subjects per strata for statistical analysis. For more information, see [5].

With all participating institutions we promoted the idea of “strategic recruitment”, where after the first broad announcement of the survey (e.g. through an email to the undergraduate engineering distribution list) as required by the IRB, the local coordinators would focus their recruitment efforts on those strata that had not yet reached their minimum targets. Strategic recruitment plans were developed by local coordinators in November 2007 and implemented as needed based on the information received in their daily response reports. Strategic recruitment also ensured that the broad population of undergraduate engineering students was not pestered with reminder emails; instead efforts were focused on the student groups where increased participation was highly desirable (for examples see [5]).

### V. Resources Required

The APPLES2 team included seven people: an overall coordinator, an IT specialist, three staff members who liaised with local campus coordinators (assisted them in planning for deployment and strategic recruitment), and two graduate students who assisted in preparing and sending the daily response reports during deployment.

Each APPLES institution had its own institution-specific survey URL. For example, Orchard University’s<sup>11</sup> APPLES URL was <http://orchard.applesurvey.org>.

Two dedicated computer servers were used to achieve high confidence in operating reliability. Aside from few variations in configuration, the software on each was identical. Moreover, each server could be quickly reconfigured to assume the full functionality of the other in case of failure. The primary server presented the survey web pages from, and collected submitted data into, a database that was replicated in real-time on the secondary server. The secondary server, doing relatively little front facing survey work, provided survey status monitoring and management dashboard displays for the APPLES2 team without negatively affecting primary server performance.

### SURVEY DEPLOYMENT & RESULTS

The total response for the survey was 4,587 from the twenty-one institutions. With data cleaning (for example, removal of ineligible respondents such as graduate students), the actual data set size was lowered to 4,266 subjects. The average survey response rate relative to the undergraduate engineering populations at the participating institutions was 14 percent. Individual school response rates varied from 49 percent at a small institution to 5 percent at a medium-large institution. Eighty-five percent of APPLES participants claimed the \$4 incentive, although only 76 percent of the incentive claimants collected the incentive. The average cost per APPLES2 participant, looking only at incentives, was \$2.65.

Eight out of the 21 institutions met all their strata targets. The most commonly missed targets were non-persisters (nine out of fourteen institutions missed this target), part-time students (four out of eight institutions missed) and ethnic minority students (four out of fourteen institutions missed). Institutions with a large number of part-time students (>30 percent) tended to have lower overall response rates than institutions with predominantly full-time students. In attempting to reach targets (particularly primary strata targets), nine institutions extended their deployment period from five days (Monday-Friday) to ten or twelve days.

We had two cases of attempted large-scale fraud, which we defined as a large number of ineligible submissions during one institution’s survey deployment. In the first case, an APPLES URL was forwarded to two “freemoney.com”-type websites. In the second case, we had two individuals repeatedly take the survey (38 times and 14 times each). Using a combination of IP tracking and timing data, we were able to identify these submissions for removal from the data set. In preparing the APPLES2 data for analysis, we also removed small-scale fraud (multiple submissions from a single IP within a suspiciously short period of time), ineligible participants, and those taking less than five minutes to complete the survey (this cutoff was based on the APPLES1 and piloting timing data).

### LESSONS LEARNED

Despite the great deal our team learned from the PIE and APPLES1 deployments, we continued to learn new lessons:

- **Individual URLs for each school were a good decision.** We had originally used institution-specific URLs for each institution’s APPLES deployment to avoid our survey appearing spam-like to students. This was a good decision for several additional reasons (some anticipated, some not). First, the individualized URLs more thoroughly protected the identity of APPLES institutions from those outside each participating institution. Second, logistically, from an IT standpoint, it was easier to track and correct specific technical problems. The scalable architecture allowed additional sites to be added more easily. The overall structure was also more robust in terms of supporting server load. Third, the instances of large-scale fraud started at individual schools, so the fraudulent data and incentive claims were more easily isolated and did not impact the larger deployment or data sets.
- **We learned more about recruiting non-persisters, transfer students and part-time students.** We had had difficulty recruiting these same student groups with the APPLES1 survey, but hypothesized then that their low response rates were due to the institutional characteristics of the four core APS institutions. However, we found these same groups difficult to recruit even with the larger sample and greater diversity of the APPLES2 institutions. Non-persisters were most successfully recruited at institutions that sent a recruitment email to technical non-engineering departments (e.g. Physics), but not all institutions had non-engineering majors and several of

<sup>11</sup> Orchard University is a pseudonym.

those with non-engineering majors faced internal constraints to contacting students in departments outside of engineering. Transfer students were most easily recruited at large public institutions and those that enrolled 3+2 engineering students. Finally, part-time students were difficult to recruit at all institutions, even those with large (>30%) part-time students enrollments. We suspected the challenge in recruiting part-time students was most likely because of their busy schedules and the incentive did not compel them to participate.

- **A last open-ended “Is there anything else you want to tell us that we didn’t already cover?” produced rich data.** Given our concerns about the length of the survey<sup>12</sup>, we almost eliminated this item prior to the APPLES1 deployment. We were glad we did not because student passions, concerns, and experiences that could not be easily captured in standard survey format were voiced here. Approximately 23 percent of the APPLES2 participants answered this optional question.
- **Staggering deployments was logistically beneficial.** The four APPLES2 deployments were staggered every other week starting in late January 2007 with four institutions participating the first week followed by eight, seven, and two institutions the following deployments, respectively. This arrangement ensured that our team was able to meet coordinator needs and allowed for last-minute survey extensions and flexibility to address anomalies with incentive claims.

### CONCLUSIONS

The Academic Pathways of People Learning Engineering Survey (APPLES) was first deployed in April 2007 at four institutions and then again in Spring 2008 at 21 more institutions in the United States. In scaling up APPLES for broad, national reach, we sampled by institution, selecting them based on institutional characteristics such as Carnegie 2000 classification and ethnic diversity. At each institution, we worked with local coordinators who assisted us in understanding local campus culture and recruiting diverse respondents. We targeted students studying engineering, those who intended to study engineering, and those who previously thought they would study engineering but ultimately chose a non-engineering major. Over 4,500 respondents participated in APPLES2. With a \$4 incentive paid through an online financial transaction company, the response rate was 14% relative to the institutional engineering enrollments.

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<sup>12</sup> Need-finding with students prior to APPLES1 suggested that the survey would need to be less than 10 minutes even with the \$4 incentive. We relied heavily on the APPLES1 piloting to streamline the instrument to this length [5].