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Measuring Cognitive Growth in Engineering Undergraduates: A Longitudinal Study

John Wise, Sang Ha Lee, Thomas A. Litzinger,
Rose M. Marra, Betsy Palmer
The Pennsylvania State University / University of Missouri /
The University of Iowa

Abstract

This paper builds on previously reported findings[1,2] by describing the completion of a four-year longitudinal investigation into the cognitive development of engineering undergraduates as measured using the Perry Scheme of Intellectual Development.[3] Fifty-four students were randomly selected during their first year and invited to participate in three hour-long interview sessions. During the interview, each student reflected on his or her view of knowledge, education, and learning. The interviews were transcribed and sent to a rater experienced in assigning positions relative to the Perry Scheme based on student responses to these types of questions. While it was hoped that students would progress from simple dualistic views (position 1 / 2) through complex dualism (position 3) and relativism (4 / 5) to commitment in relativism (position 6+), most students in this sample did not make it beyond position four. This paper will review the findings with an eye towards curricular activities that may or may not encourage this type of growth.

I. Introduction

The move towards more active learning in engineering education has brought with it a need to assess the higher-order thinking that such environments and activities are thought to promote.[3] At Penn State, we have been looking at undergraduate student development using the Perry scheme of intellectual development as a way to identify factors that contribute to the cognitive growth of students during a four or five year engineering program.

William Perry began asking undergraduates about their experiences at Harvard in the 1950s. [3] Using an open-content interview method, Perry was able to collect data reflecting the students' epistemology. Common themes began to emerge, and he was able to identify what appeared to be a series of "positions" that change as the student experiences situations that are dissonant with their cognitive structures. The scheme begins with basic dualism (positions 1 and 2), proceeds through relativism (positions 3 through 5) and concludes with commitment within relativism (positions 6 through 9) [Table 1.]

Position	Family	Label	Characteristics
1	Dualism	Basic Duality	Dualistic structure of the world unquestioned. Good/Bad, Us/Them, Right/Wrong
2	Dualism	Multiplicity Pre-Legitimate	Multiplicity is perceived, but not believed. Authority still holds answers.
3	Dualism	Multiplicity Subordinate	Multiplicity perceived, but trust in authority to eventually find answers is not shaken.
4	Relativism	Multiplicity Correlate or Relativism Subordinate	All opinions equally valid. Authority "wants us to think" that relativism exists.
5	Relativism	Relativism Correlate, Competing, or Diffuse	Relativism accepted intrinsically.
6	Relativism	Commitment Foreseen	Relativism accepted, commitment seen as necessary to operate in a relativistic world.
7	Commitment	Initial Commitment	First commitments made
8	Commitment	Orientation in Implications of Commitment	Adjustments due to commitment
9	Commitment	Developing Commitment(s)	Commitments continue

Table 1. Major Positions on Perry Scheme [3]

While college students may typically begin their first year as intellectual dualists, believing that experts know the "truth", they are soon confronted with situations that test this basic faith. With each new dissonant experience, the student is compelled to resolve the dissonance either by adapting his or her cognitive schema or rejecting the authenticity of the experience. Adaptation moves the student forward in the Perry scheme. Rejection represents actions that Perry termed as "escape" or "retreat" – a refusal to move forward. Such students may delay progress for an extended time, as they re-gather the energy they will need to change. Others may remove themselves from the situation that precipitated the conflict. For the most part, students who entered as dualists should tend to graduate with a more sophisticated view, recognizing the need to gather evidence from multiple sources and make their own judgments. This change is desirable for developing engineers who can solve complex engineering problems and who are responsible for their own continued learning in the world at large.[5]

A student's position within the Perry scheme can be difficult to determine. Several methods have been developed, but the open-ended interview is generally agreed to produce the richest data.[6,7]

II. Method

Our longitudinal cohort began with fifty-two first-year students who were randomly selected from a database containing all students entering the college of engineering in the Fall of 1996. These students agreed to come in and be interviewed in the Spring of 1997, after one semester on campus. These fifty-two students were invited back in the fall semester of their third year and asked to repeat the interview. Thirty-nine consented to participate, but technical difficulties with the recording equipment resulted in only thirty-two interviews being rated. Finally, these students were contacted in the fourth year of their studies for a final interview, and twenty-seven agreed. All of these interviews yielded ratings from the expert rater. The final sample provided longitudinal data for twenty-one students at all three collection points. We limit our findings to the data derived from these twenty-one students unless otherwise indicated [Table 2].

Interview Number	**Usable Data**	**Semester Interviewed**
1	n=52	Spring 1997 (Semester 2)
2	n=32	Fall 1998 (Semester 5)
3	n=27	Spring 1999 (Semester 8)
All Interviews	n=21	(n/a)

Table 2. Data Collection Schedule

All interviews were videotaped and sent to an "expert rater" at the Institute for the Study of Intellectual Development in Washington State for analysis.[8] A rating was assigned based on a three-digit coding scheme, and a decimal equivalent was used for statistical analysis [Table 3].[1,9]

Rating	Dominant Position	Decimal Equivalent	Trend
222	2	2.0	Stable
223	2	2.33	Opening to 3
233	3	2.67	Not fully developed
333	3	3.0	Stable
334	3	3.33	Opening to 4
344	4	3.67	Not fully developed
etc.			

Table 3. Perry ratings as assigned by expert rater with decimal equivalents

III. Findings

As expected, the first-year students averaged 333 / 3.27 on the Perry scale, indicating a dualistic approach in their thinking similar to that found among first-year students in several other studies.[8] The lowest rating for this group was 223 / 2.33 (n=1) and the highest was 444 / 4.0 (n=1), with a standard deviation of 0.40. Position four is advanced for a first-year student, and indicates recognition of the relativistic nature of knowledge. A factor of interest for the first-year data is the positive effect of a first-year design course that is offered to non-computer majors. Marra et al. previously reported this effect for the first-year group, but the significance was not maintained when the sample was reduced from fifty-two to twenty-one in this study.[1]

The second interview, held almost two years later, showed very little forward movement relative to the Perry scale. The mean rose to 334 / 3.33, indicating an overall opening to position four as opposed to the position three stability of the first year student – but still a predominantly dualistic thought process. After completing two years of undergraduate education, most of these students still looked to their professors and other authorities as the "fount of knowledge". The ratings ranged from 233 / 2.67 (n=2) to 444 / 4.00 (n=1), with a standard deviation of 0.35. The previously observed effect of the first year design course was no longer evident for the third-year students. However, an analysis of the students who dropped from the study between the first and second interview shows that higher-scoring students were more likely not to return. Although this finding did not rise to the level of statistical significance, it is important when considering whether or not the design course effect has been maintained through the third year. We cannot with confidence say that the failure to show a maintenance effect is not due to mortality in the sample.

The final interview yielded an average rating of 444 / 4.19 (standard deviation = 0.523), with a low of 334 / 3.33 (n=3) and a high of 555 / 5.0 (n=1). The first-year design effect did not re-surface at this time. Figure 1 illustrates the mean ratings for all three interviews.

Perry Ratings

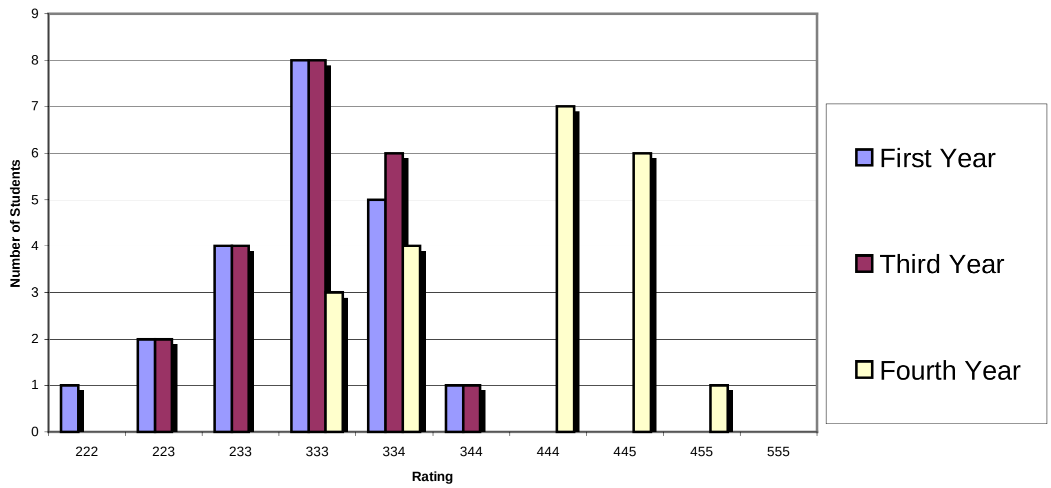

Figure 1. Mean Ratings over Three Interviews

Table 4 contains the results of an analysis of variance conducted on the three groups of Perry ratings, with school year and first-year design experience as factors.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
School Year	2	11.1084	9.1402	4.5701	24.02	0.000
Design	1	0.0088	0.0088	0.0088	0.05	0.831
Interaction	2	0.3279	0.3279	0.1640	0.86	0.428
Error	39	10.8454	10.8454	0.1903		
Total	42	22.2905				

Table 4. Analysis of Variance

Given the strength of the "school year" factor ($F=24.02$, $p<0.001$), a follow-up test was conducted to determine specific differences. With a family significance level of $\alpha=0.01$, a Bonferroni test indicated a significant group mean difference between first and fourth-year and between third and fourth-year student scores. There was no significant group mean difference between first and third-year students. (Figure 1 again illustrates this relative lack of growth in the first year to third year interval as compared to the third year to fourth year interval). The overall change of one Perry position (from 3 to 4) over the four-year span is consistent with other research findings.[10] Our students as a whole did not pass the critical position 5 that would indicate what some consider to be required for complex, real world problem-solving, although 33% did achieve that level.[5,10]

As with most longitudinal studies, we experienced some difficulty with the mortality of the sample. Our second interview contained only 62 % of the original sample, the third interview only 52% of the original (although it was 84% of the second group), and only 38% of the original sample contributed data at all three collection points. We conducted analyses comparing the students who left the study with those who remained using previous Perry rating and GPA and found no statistically significant factor that would lead us to conclude that there were differences between the two groups (Perry Rating p=0.54, GPA p=0.97). There was a tendency for the higher ratings to drop out, but this did not rise to the level of significance.

IV. Discussion

In addition to the mortality of our sample, we had additional difficulties maintaining our methodology. We used 10 different interviewers over four years and did identify possible interviewer effects with our cross-sectional data. We switched from video to audiotapes to written transcript analysis over the life of the study and cannot account for possible variation caused by these changes. With these limitations in mind, there are still some things that can be said regarding our findings.

It appears that little cognitive growth takes place during the first two years of undergraduate instruction. It is during this time that most students take required, fundamental courses such as calculus. Most if not all of the required courses are presented in the traditional lecture format, with the professor giving out information that the students will need to retrieve for the test that will follow. Little cognitive load beyond rote memorization and application of formulae is placed on the student, and the amount of information presented for memorization allows little free time for reflection. This environment tends to reinforce dualistic thinking, as the key to success is almost certainly to listen to authority (the professor) and repeat back the static knowledge thus obtained. It is interesting to note the apparent positive impact of the first year design course on the student's Perry rating, although that effect is not sustained. Is this because the curriculum does not reinforce open-ended problem solving until the third year?

If this hypothesis is correct, then the apparent jump in ratings indicated between the third and fourth year may be directly attributable to the changed environment in which the student finds him/herself. Having officially entered an engineering major (in most cases), the coursework begins to include projects and team activities that place the learners in contact with those forces most likely to advance their thought processes: the thoughts, opinions, and ideas of others like themselves.

The positive growth between the third and fourth years should not mask the fact that Perry position four is still well behind what we should hope for our engineering graduates. It is actually not too difficult to convince an undergraduate that "all opinions are equally valid", a statement congenial to a position four thinker.[3] What is proving more difficult is finding a way to move into the higher levels, those that indicate a *commitment within relativism*, a more complex view that recognizes that problems have more than one solution but that some solutions may, in fact, be *better* than others – but a commitment must be made in order to advance on the problem. If we hope to help students reach these higher levels of thought, we may need to restructure the first two years of the college experience, exposing them to more complex modes of thinking through realistic, situated problem-solving and other active-learning activities.

V. Recommendations

Further research is needed to test the effect of first-year design courses on the intellectual development of undergraduates to determine if curricular changes in the first two years can indeed take juniors and seniors to higher levels of cognition. This study gathered information on a longitudinal cohort through four years. It is near impossible to ascribe growth to any one experience. In order to test the specific effect of the design course, a more traditional pre/post test design should be used.

If the Perry scheme is to be used to assess the effectiveness of curricular changes, it will need to be more practical in terms of both time and expense. A more easily-scored objective instrument would be ideal, but has been historically difficult to produce. Further research on instrument development is obviously needed.

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360-786-5094 (voice) 503-212-8082 (efax), William Moore, wsmoore51@home.com.
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JOHN WISE
John Wise is Director of Engineering Instructional Services at Penn State. In this capacity, he provides assistance to faculty members and teaching assistants in the areas of teaching, learning, and instructional technology. He received his B.A. in Liberal Arts from The University of the State of New York and his M.S. in Instructional Systems from Penn State. He is currently completing his dissertation research on intellectual development of engineering students as a doctoral candidate in Instructional Systems. He may be reached at jwise@psu.edu.

SANGHA LEE

Sangha Lee is a doctoral candidate in Educational Psychology at Penn State. He earned his M. Ed. in Mathematics Education and B.S. in Mathematics Education from the Korea National University of Education and taught mathematics in Korea for eight years.

THOMAS A. LITZINGER
Thomas A. Litzinger is currently Director of the Leonhard Center for the Enhancement of Engineering Education and a Professor of Mechanical Engineering at Penn State, where he has been on the faculty for 15 years. Prior to his appointment as Director of the Leonhard Center, he was ECSEL local principal investigator and the Coalition-PI for Student and Faculty Development. His work in engineering education involves curricular reform, teaching and learning innovations, faculty development, and assessment. He has received the Eisenhower Award for Distinguished Teaching at Penn State as well as the Premier and Outstanding Teaching Awards from the Penn State Engineering Society (PSES). He has also received an Outstanding Research Award from PSES and an NSF Young Investigator Award. Prior to joining Penn State, Dr. Litzinger had four years of industrial experience with General Electric in power systems, and completed his Ph. D. studies at Princeton.

ROSE M. MARRA
Rose M. Marra is an Assistant Professor in the School of Information Science and Learning Technologies. Her primary teaching areas include the assessment and evaluation of instructional innovations, instructional design and development, project management of instructional design experiences, and effective uses of technology for K-12 teachers. Prior to joining the faculty at the University of Missouri in 2000, she worked as the Director of Engineering Instructional Services in Penn State University's College of Engineering. In this capacity, Dr. Marra worked with the college faculty to develop curricula, introduce effective uses of technology into engineering classrooms and assess the effects of these educational changes on student performance. Current research interests and activities include implications and limitations of online learning, technology integration for teacher education and studying the intellectual development of engineering students.

BETSY PALMER

Betsy Palmer is an Assistant Professor in the Department of Counseling, Rehabilitation and Student Development at the University of Iowa. Her research interests include college student intellectual development, postsecondary curriculum and teaching, and multiculturalism in higher education. Prior to her appointment at the University of Iowa, she was an assistant professor of Higher Education at the University of Alabama. She completed her Ph.D. in Higher Education at the Pennsylvania State University where she was employed as a graduate research assistant for the College of Engineering.