The Role of Introductory Course Grades in Engineering Disciplinary Cultures

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***Abstract*—This work-in-progress paper builds on research that has found disciplinary differences in culture, demographics at initial enrollment ("starters"), demographics of students migrating later, and various student outcomes for both groups. An earlier longitudinal study using the Multiple-Institution Database for Investigating Longitudinal Development (MIDFIELD) showed no disciplinary stratification of grades in common early engineering courses based on the discipline in which a student matriculates (or first enrolls after a first-year engineering program). In contrast, this study finds that disciplinary differences in introductory courses emerge on the path to graduation. This can only be explained by a bias with respect to introductory course grades of students entering and leaving each major– students with lower grades in introductory courses are more likely to leave or be attracted by some majors than others. Citing prior research regarding cultural differences among the engineering disciplines, the authors propose that disciplines establish and enforce cultural norms regarding student performance in these introductory courses.**

Keywords—disciplinary culture, grades, stratification

I. Introduction

When considering differences among engineering disciplines, grades are a common starting point. Course grades have an obvious role in academic progression. Grades in prerequisite courses are used to provide or deny access to later courses. A variety of events including graduation, probation, and expulsion are tied to student grade-point averages (GPAs) [1]. Grade-point averages also serve as gatekeepers to scholarships [2], special programs such as cooperative education [3], and job interviews [4]. In times of enrollment management, GPAs can be gatekeepers to access to particular disciplinary pathways [5]. Although academics and professionals frequently express concern that students are more worried about their grades than learning [4], it is clear that grades can influence the pathways open to students and their success in those pathways. Whereas the consideration of student grades in enrollment management can produce explicit policy-based differentiation among engineering disciplinary populations, grades also form part of the basis for ruling relations of cultural inclusion and exclusion that determine who belongs [6]. This latter use of grades is of particular concern in this work—the extent to which the students and instructors of a discipline use grades in early courses to determine who belongs.

II. Earlier Investigations of Grades in Engineering

The grades of engineering students have been explored by various researchers. Although results from the National Survey of Student Engagement (NSSE) show that engineering students self-report that they are less likely to have high GPAs and more likely to have lower GPAs than students in other majors, a detailed analysis revealed that those results are not statistically significant, and a longitudinal study of student records from multiple institutions revealed that engineering students had grade distributions similar to that of students in other groups of majors [7].

Rask proposed differences in grading practices as a driver of attrition from Science, Technology, Engineering, and Math (STEM) to disciplines with more lenient grading practices [8], a question explored by others as well [9-13]. Most relevant to the present work is the work of Mumford, Main, and Ohland studying the role of grades in major selection and switching within the context of engineering [14]. They found that disciplinary differences in the proportion of A grades awarded varied from 23% (Mechanical Engineering) to 33% (Industrial Engineering).

Mumford, Main, and Ohland also discovered that expected grades and previous performance affect the likelihood that students will switch majors within engineering [14]. They found that students with higher grades in introductory courses were more likely to remain in their intended major. Students with lower introductory course grades were more likely to switch majors—in some instances, changing majors even when the switch would be expected to result in lower overall GPAs. Not surprisingly, student decision making related to persistence in a student's original intended major or switching to another engineering major is a complex process. This work-in-progress holds promise to reveal more of that complexity by providing evidence to suggest a mechanism by which disciplinary culture plays a role in that process.

Our general hypothesis in pursuing this work was that disciplinary differences in the grades in introductory courses would emerge toward graduation. We had two more specific hypotheses based on interviews of women in Chemical Engineering and Industrial Engineering at a subset of the same

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institutions from which the quantitative data were obtained [15]—that Industrial Engineering would be more welcoming of students regardless of their introductory course grades, consistent with the moniker "Inviteful Engineering" coined in [16], and that Chemical Engineering would be notably more restrictive—consistent with themes from [17].

III. Data Source and Preliminary Methods

The Multiple-Institution Database for Investigating Longitudinal Development (MIDFIELD) is a longitudinal, whole population dataset including de-identified longitudinal data from multiple institutions. The dataset is large enough to disaggregate data by multiple characteristics such as race/ethnicity, sex, and discipline simultaneously. The dataset documents precollege information, student pathways (including courses), and graduation records. More details about the dataset are available in [18]. It contains data from the whole population rather than a sample, so no inference is needed to generalize the findings within this set of institutions and there is no basis to compare these findings to those of a larger dataset. To the extent possible, congruence between MIDFIELD and a national database maintained by the American Society for Engineering Education has been established [19]. All differences are population differences so it is unnecessary to discuss statistical tests and p-values. Future work will report variances and effect sizes as well as graphical representations.

The preliminary analysis for this Work-in-Progress was conducted on an earlier set of 11 institutions (other institutions have been added to MIDFIELD subsequently). This was to establish a comparison to previously published results from MIDFIELD that described the grades in introductory courses earned by students *starting* in various disciplines shown in Table I [16], rather than the students *graduating* in those disciplines, which is the focus of this work. Of course, these two populations are not equivalent, because this is not a closed system. Some of those *starters* will graduate in engineering majors not studied, graduate in non-engineering majors, or not graduate at all due to the complexity of the engineering education ecosystem [20]. We focus on the five engineering disciplines that have the most students and programs across the USA and account for at least 75% of engineering students in MIDFIELD: Chemical Engineering (CHE), Civil Engineering (CVE), Electrical Engineering (ECE), Industrial Engineering (ISE), and Mechanical Engineering (MCE). A detailed rationale for our choice of disciplines can be found in [20]. GPA has a maximum value of 4.0 (A), and the minimum GPA at graduation is 2.0 (C).

TABLE I. GPA in Common Courses of Students Starting in Selected Engineering Disciplines, Results from [15].

Courses included are Calculus I, II, II, Physics I, II, and Chemistry I	GPA	
Student major at the start of 3rd semester.	**Men**	**Women**
Chemical Engineering (CHE)	2.77	2.79
Mechanical Engineering (MCE)	2.60	2.66
Civil Engineering (CVE)	2.54	2.63
Industrial Engineering (ISE)	2.49	2.63
Electrical Engineering (ELE)	2.64	2.59

Since we are studying outcomes for students who graduate, students are only included in this study if sufficient data are available to calculate a six-year graduation rate to avoid the systematic majority measurement bias observed when shorter graduation times are expected [21]. Since graduation rate is not the outcome of interest, however, students are included even if they graduate outside that six-year window. Since many transfer students will not have recorded grades for the courses of interest, the study includes only first-time-in-college students.

To expand upon the earlier work, multiple time points are identified for this study: matriculation in each major (where selecting a specific engineering major at matriculation is possible), the subset of those students remaining in Semester 3, all students enrolled in each major at Semester 3, and all students graduating in each major. Whereas the total enrollment at Semester 3 still excludes transfers, it adds in students from first-year engineering (FYE) programs that select a major after completing required FYE courses, students who matriculated in a different engineering major from their current major (including engineering majors not shown such as Ocean Engineering), and students who matriculated in non-engineering majors who switched into one of these majors. As this is a Work-in-Progress, the data are not disaggregated by sex or race/ethnicity as will be included as this work continues.

IV. Findings

The findings from the current study are shown in Table II.

TABLE II. GPA in Common Courses of Students Enrolled in Selected Engineering Disciplines at Various Timepoints.

Courses included are Calculus I, II, II, Physics I, II, and Chemistry I	GPA in those courses for population shown at left				
Population studied	**ChE**	**ELE**	**MCE**	**CVE**	**ISE**
Number at Semester 3	5999	10141	13163	6438	4671
Number at graduation	4284	7418	10012	6334	5546
Students matriculating directly to each major	2.56	2.46	2.41	2.39	2.43
Students matriculating directly remaining 3rd sem.	2.65	2.58	2.52	2.49	2.48
Students enrolled 3rd sem.	2.82	2.74	2.73	2.63	2.63
All students graduating	3.09	2.99	2.89	2.65	2.61

A few things are observable in Table II:

- The disciplinary variation of matriculating students and third semester students is small, but the variation increases by graduation.
- When the disciplinary columns of Table II are sorted by the introductory course GPA of students in each discipline, each of the other rows remain similarly ordered, with the minor exception of ISE at matriculation, where there is little variation in any case. That is, the ordering of the disciplines by GPA remains essentially the same at each timepoint.
- The average GPA in these introductory courses increases for all majors at successive timepoints, with the minor exception of the introductory course GPA

for ISE at graduation, which remains nearly constant from the third semester.
- The change in average introductory GPA in CHE, MCE, and ELE is driven more by attrition, whereas that of CVE and ISE clearly includes migration.

V. Discussion

All disciplines exhibit an increase in the average introductory course grades as students advance in the curriculum, which is not surprising, since students at the lowest end of that grade distribution are likely to be disqualified from continuing by policy—either because they cannot maintain the minimum GPA required to continue or because they could not earn sufficiently high grades in pre-requisite classes to advance. Stratification emerges because some disciplines lose a higher proportion of students with lower grades in those courses. This, in combination with earlier research on the culture of disciplines, suggests that there may be cultural expectations for who "belongs" in each discipline based on their grades in those early courses. These cultural expectations likely commingle with other cultural expectations of belonging creating a complicated dynamic of inclusion, particularly for students likely to be marginalized for other reasons.

The dynamics of cultural transmission are complex, and the messages about who "belongs" are likely to be delivered and reinforced by students, instructors, advisors, administrators, and departmental policies. This work presents no new qualitative research, but links the present findings to other qualitative and quantitative research to propose a cultural explanation of the observed phenomenon.

The mindset or lens through which these results are interpreted are critically important. For example, since Industrial Engineering has been referred to as "Imaginary Engineering" [22], the findings might at first suggest to some that Industrial Engineering is a "dumping ground" for students who cannot succeed in other majors. Noting the increase of the average course grades for all majors, however, suggests a wholly different interpretation. Just as Industrial Engineering has been described as "inviteful," [16], the findings suggest to us that Industrial Engineering is the most welcoming of students who are succeeding in the major even though their introductory grades were not as high as those of students in other disciplines. This is supported by other work that has shown that ISE is more diverse than other engineering disciplines [23]. This suggests that disaggregating these results by race/ethnicity, sex, and course will provide greater insights. In that extension of this work, it will be particularly interesting to explore Civil Engineering, which was unique among these five disciplines to show racial/ethnic variability in the rate of migration from other disciplines and the graduation rate of migrators, whereas the other four disciplines showed gendered variability in those metrics [20].

This work connects to significant explorations of the culture of higher education, engineering and specific engineering disciplines. As this work continues, we will explore how disciplinary hierarchies have been posited historically in the work of Comte [24] as early as 1896 and modeled by others more recently [25, 26]. We will situate this work in descriptions of engineering culture such as the "meritocracy of difficulty" [27] and the enactment-externalization dialectic [28]. We will also consider descriptions of the culture of specific engineering disciplines, particularly studies of Industrial Engineering [15, 16, 22, 23] and Chemical Engineering [17, 29], the disciplines at the extremes of variability in our findings as well as multidisciplinary studies of engineering disciplinary cultures [30-32].

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References

[1] C. E. Brawner, S. A. Frillman, and M. W. Ohland, "A Comparison of Nine Universities' Academic Policies from 1988 to 2005." (ERIC: ED508293), February 2010, 42 pages.

[2] F. C. Mobley, C. E. Brawner, and M. W. Ohland. "The South Carolina merit scholarship: Strategies used by engineering students to keep their LIFE scholarship." *International Journal of Engineering Education*, vol. 25, no. 6, pp. 1249-1256, 2009.

[3] J. B. Main, N. M. Ramirez, B. N. Johnson, H. Ebrahiminejad, M. W. Ohland, and E. A. Groll. "A case for disaggregating engineering disciplines in engineering education research: The relationship between co-op participation and student persistence." *International Journal of Engineering Education*, vol. 36, no. 1(A), pp. 170–185, 2020.

[4] J. H. McMasters, "Influencing student learning: An industry perspective." *International Journal of Engineering Education*, vol. 22, no. 3, pp. 447, 2007.

[5] Purdue University College of Engineering, "Enrollment Management Policy for FYE Students - College of Engineering - Purdue University." https://engineering.purdue.edu/Engr/InfoFor/CurrentStudents/enrollment-policy, 11/20/2016.

[6] A. L. Pawley, "Learning from small numbers: Studying ruling relations that gender and race the structure of US engineering education," *Journal of Engineering Education*, vol. 108, no. 1, pp. 13-31, 2019.

[7] M. W. Ohland, S. D. Sheppard, G. Lichtenstein, O. Eris, D. Chachra, and R. A. Layton, "Persistence, engagement, and migration in Engineering," *J. Eng. Ed.,* vol. 97, no. 3, pp. 259-278, 2008.

[8] K. Rask, "Attrition in STEM fields at a liberal arts college: The importance of grades and pre-collegiate preferences," *Economics of Education Review*, vol. 29, no. 6, pp. 892–900, 2010.

[9] B. Ost, "The role of peers and grades in determining major persistence in the sciences," *Economics of Education Review*, vol. 29, no. 6, pp. 923–934, 2010.

[10] J. B. Main and B. Ost, The impact of letter grades on student course selection and major choice: evidence from a regression-discontinuity design, 2011, CHERI WP 142. https://www.ilr.cornell.edu/sites/ilr.cornell.edu/files/WP142.pdf.

[11] A. Owen, "Grades, gender, and encouragement: A regression discontinuity analysis," *Journal of Economic Education*, vol. 41, no. 3, pp. 217–234, 2010.

[12] K. N. Rask and J. M. Tiefenthaler, "The role of grade sensitivity in explaining the gender imbalance in undergraduate economics," *Economics of Education Review*, vol. 27, no. 6, pp. 676–687, 2008.

[13] J. B. Main and B. Ost, "The impact of grades on student effort, course selection, and major choice: A regression-discontinuity analysis," *Journal of Economic Education*, vol. 45, no. 1, pp. 25–35, 2014.

[14] J. Main, K. J. Mumford, and M. W. Ohland, "Understanding migration patterns of engineering undergraduates: Major intent, course grades, and major choice," *International Journal of Engineering Education,* vol. 31, no. 6A, pp. 1468–1475, 2015.

[15] C. E. Brawner, M. M. Camacho, S. M. Lord, R. A. Long, and M. W. Ohland, "Women in industrial engineering: Stereotypes, persistence, and perspectives," *Journal of Engineering Education*, vol. 101, no. 2, pp. 288-318, 2012.

[16] D. A. Trytten, R. L. Shehab, T. Reed-Rhoads, M. J. Fleener, B. J. Harris, A. Reynolds, S. E. Walden, S. K. Moore-Furneaux, E. Kvach, K. R. Warram, and T. J. Murphy, "'Inviteful' engineering: Student perceptions of industrial engineering," *Proceedings of the the ASEE Annual Conference*, Salt Lake City, UT, 2004.

[17] C. E. Brawner, S. M. Lord, R. A. Layton, M. W. Ohland, and R. A. Long, "Factors affecting women's persistence in chemical engineering," *International Journal of Engineering Education,* vol. 31, no. 6A, 2015, pp. 1431–1447.

[18] M. W. Ohland and R. A. Long, "The Multiple-Institution Database for Investigating Engineering Longitudinal Development: An experiential case study of data sharing and reuse," *Advances in Engineering Education,* vol. 5, no. 2, pp. 1-28, 2016.

[19] M. K. Orr, M. W. Ohland, S. M. Lord, and R. A. Layton, "Comparing the Multiple-Institution Database for Investigating Engineering Longitudinal Development with a National Dataset from the United States," *International Journal of Engineering Education*, in press.

[20] S. M. Lord, M. W. Ohland, M.M. Camacho, and R. A. Layton, "Beyond pipeline and pathways: ecosystem metrics," *Journal of Engineering Education*, vol. 108, no. 1, pp. 32-56, 2019.

[21] M. W. Ohland, C. E. Brawner, M. M. Camacho, R. A. Layton, R. A. Long, S. M. Lord, and M. H. Wasburn. "Race, gender, and measures of success in Engineering Education," *J. Eng. Educ*., vol. 100, no. 2, pp. 225-252, 2011.

[22] C. E. Foor, and S. E. Walden, "'Imaginary Engineering' or 'Re-imagined Engineering': Negotiating Gendered Identities in the Borderland of a College of Engineering." *NWSA journal*, vol. 21, no. 2, pp. 41-64, 2009.

[23] M. Pilotte, M. W. Ohland, S. L. Lord, M. K. Orr, and R. A. Layton, "Student Demographics, Pathways, and Outcomes in Industrial Engineering," *International Journal of Engineering Education*, vol. 33, no. 2A, pp. 506-518, 2017.

[24] A. Comte, "The positive philosophy of Auguste Comte, Vol. 1," (H. Martineau, Trans.). London: George Bell & Sons. Retrieved from http://babel.hathitrust.org/cgi/pt?id=mdp.39015009198121, 1896.

[25] J. Beyer Lodahl, and G. Gordon, G., "The structure of scientific fields and the functioning of university graduate departments," *American Sociological Review*, vol. 37, no. 1, pp. 57–72, 1972.

[26] L. D. Smith, L. A. Best, D. A. Stubbs, J. Johnston, and A. B. Archibald, "Scientific graphs and the hierarchy of the sciences: A Latourian survey of inscription practices," *Social Studies of Science*, vol. 30, no. 1, pp. 73–94, 2000.

[27] R. Stevens, D. Amos, L. Garrison, and A. Jocuns, "Engineering as lifestyle and a meritocracy of difficulty: Two pervasive beliefs among engineering students and their possible effects." *Proceedings of the the ASEE Annual Conference*, Honolulu, HI, 2007.

[28] P. M. Leonardi, M. H. Jackson and A. Diwan, "The enactment-externalization dialectic: Rationalization and the persistence of counterproductive technology design practices in student engineering," *Academy of Management Journal*, vol. 52, no. 2, pp. 400–420, 2009.

[29] S. M. Lord, R. A. Layton, M. W. Ohland, C. E. Brawner, and R. A. Long, "A multi-institution study of student demographics and outcomes in chemical engineering," *Chemical Engineering Education,* vol. 48, no. 4, pp. 231-238, 2014.

[30] E. Godfrey, "Cultures within cultures: Welcoming or unwelcoming for women?" *Proceedings of the the ASEE Annual Conference*, Honolulu, HI, 2007.

[31] E. Litzler, "Sex segregation in undergraduate engineering majors," Doctoral dissertation, 2010.

[32] R. Marra, B. Bogue, and D. Shen, "Engineering classroom environments: Examining differences by gender and departments," *Proceedings of the the ASEE Annual Conference*, Pittsburgh, PA, 2008.