

AC 2008-1678: THE EFFECTS OF INSTRUCTORS' TIME IN INDUSTRY ON STUDENTS' CO-CURRICULAR EXPERIENCES

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The Effects of Instructors' Time in Industry on Students' Co-Curricular Experiences

Abstract

Evidence indicates engineering graduates' skills are misaligned with workforce needs. Are the disjunctions due, in part, to the backgrounds of students' instructors? Using a nationally representative sample of 1,037 faculty and 3,338 students representing 142 programs on 39 campuses, findings indicate that graduates of programs with a higher proportion of faculty with industry experience report spending more time in non-required design activities and competitions than students in programs with more academically oriented faculty. The expectation that students in such programs would also report more time spent in internships and cooperative education experiences and that they would be more involved in student chapters of professional societies was not confirmed.

Introduction

Engineering education plays a vital role in the preparation of America's workforce and its competitiveness in the global economy. All may not be well, however, as disjunctions emerge between workforce needs and recent graduates' skills, particularly in the professions. During the 1990s, engineering programs came under fire for failing to adequately prepare graduates to face the challenges of engineering practice. Critics found newly minted engineers highly skilled in mathematical and scientific foundations but ill-prepared to solve unstructured problems, communicate effectively, or work in groups – all essential skills in the modern engineering workplace.

Finkelstein, Seal, and Schuster¹ claim that "the story of American higher education experience . . . can be told in substantial part by recounting just who made up the faculty over time" (p. xi), that the graduates a program produces are a function of the kinds of faculty members who teach them. In engineering, as well as in other professional disciplines, these faculty members have become increasingly academic in their backgrounds over the past century and increasingly removed from the industries they serve. Jencks and Riesman² first noted the tendency of professional schools to drift from their applied, action research roots toward more scholarly activities, and engineering education is a case-in-point. The post-WWII and Sputnik eras saw a massive influx of federal support for research in higher education, increased hiring of research-oriented faculty members, and curriculum revisions that reflected faculty members' interests. By 2000, engineering education looked more like that in a traditional science than in a profession.³ Government, business, and professional societies pressed for engineering education reforms in order to sustain America's technological and economic leadership.

Consistent with Finkelstein et al.,¹ one explanation for the failure of engineering programs to provide graduates with important professional skills is that most engineering students are taught by faculty with little or no industry experience.⁴ Faculty removed from advances in industrial practices, the argument goes, are likely to be slow in identifying the shifting needs of industry and in adjusting the curriculum and their teaching practices accordingly. Faculty members with industry experience are presumably more attuned to the

skills needed in the workplace and more experienced than their more academic colleagues in helping students appreciate and apply their science-based coursework in engineering project problem-solving.

Despite the widespread belief among both professional and academic engineers that faculty members with substantial industry experience have a great deal to offer students, however, a literature review reveals little empirical evidence to support that argument. In interviews with administrators, Baldwin and Chronister⁵ found that "deans and chairs of professional fields stated that hiring full-time non-tenure-eligible faculty who have extensive [non-academic] experience. . . enriches the curriculum for students and regular faculty." The claim, however remains untested. Baldwin and Chronister's study also reveals that engineering deans and chairs consider these instructors as a separate cadre of faculty, distinct from tenured and tenure-track academics. Such perceptions may suggest that tenure-eligible faculty do not have the necessary experience to enrich educational experience in this way. Those perceptions may also indicate that industry experience is not valued as much as scholarly credentials in salary and promotion and tenure decision-making.

This study tests the proposition that students enrolled in programs having a higher proportion of faculty members with industry experience will have a different set of program experiences than similar students in programs having faculty members with more academic backgrounds and orientations. Differences in a number of students' experiences might, of course, be assessed, but it seems reasonable to expect industry-experienced faculty members' influence to be most apparent in student experiences that closely resemble the "real" engineering world. Thus, this study examined the influence of faculty background on students' out-of-class, engineering-related experiences.

Importance of the Co-Curriculum

This study considered three co-curricular experiences known to positively influence student learning outcomes⁶ –internships or cooperative education, non-required design activities and competitions, and involvement in student chapters of professional societies. A small but fairly consistent body of evidence indicates that students' participation in internships positively influences the development of their professional skills. Pascarella and Terenzini^{7,8} reviewed the literature relating to work during college, including part-time work, internships, and coops, and concluded that “employment during college enhances the development of career-related skills.” While most of these studies were based on student self-reports of the benefits of these work experiences, data from employers suggests that they agree with students’ self-assessments. Casella and Brougham⁹ found that a majority of employers they surveyed reported that students with work or internship experience “produced higher-quality work, accepted supervision and direction more willingly, demonstrated better time management skills, and were better able to interact with coworkers on team projects.” Similar to internships, the influence of coops might be expected to be even stronger because these experiences are typically longer in duration and more integrated than traditional internships with the engineering academic experience. In a study at one institution, for example, Hackett, Croissant, and Schneider¹⁰ found that even after students’ pre-college characteristics were controlled, coop experience positively and significantly influenced engineering students’ professional skills. In addition to supporting the findings

linking work experience to increased professional skills, Lattuca, Terenzini, and Volkwein⁶ found internships and cooperative education to be positively related to a number of applied skills including engineering skills, experimental skills, and design and problem-solving.

Dym and colleagues¹¹ assert that “the purpose of engineering education is to graduate engineers who can design, and that design thinking is complex.” Because of the importance of design in engineering education, efforts are ongoing to integrate design throughout the undergraduate curriculum, rather than reserving it for a single capstone course. Many students supplement their in-class design activities with non-required participation in design competitions. Focusing on the ABET learning outcomes, Lattuca, et al.⁶ found that student participation in design competition significantly and positively influenced students’ self-reported skills and abilities, including design and problem-solving skills, experimental skills, and life-long learning skills. While the literature has only a small number of studies linking students’ participation in non-required design activities with specific outcomes, academic programs continue to sponsor and encourage student participation in design competition.

Like work experience and design competitions, participation in student chapters of professional societies provides important benefits to students. Litzler, Lange, and Branard¹² found that student society participants reported participating in greater number of on-campus job interviews, higher salaries, and greater confidence in skills related to their major than non-participants. The Lattuca et al.⁶ study found that student participation in professional societies significantly and positively influenced a range of students’ self-reported skills and abilities including their ability to apply engineering skills, communication skills, and knowledge of societal and global issues. While the number of studies exploring the influence of student participation is small, the results consistently indicate a positive relationship between participation and student outcomes in career-related areas.

That student co-curricular experiences, including those described above, affect learning seems reasonably well-established^{7,8} but the variables that shape these experiences are less well understood. Recognizing the co-curriculum as a place where faculty may encourage students to connect their theoretical skills with the real world, this study assessed whether faculty members with industry experience (compared to their colleagues without it) did, indeed, stimulate greater student involvement in co-curricular activities related to engineering, as well as the dynamic that may underlie that influence. The answers have implications reaching beyond engineering to education in virtually all professions, including business, law, education, medicine, and social work.

Methods

This study employs an *ex post facto*, cross-sectional survey design utilizing data collected from a national study of engineering faculty and students.¹³ The study uses a nationally representative sample of ABET-accredited programs in the seven engineering fields (aerospace, civil, chemical, computer, electrical, industrial, and mechanical) that produce approximately 80% of all baccalaureate degrees in any given year. The target population for the study included the 1,024 ABET-accredited engineering programs in the seven disciplines at 244 US colleges and universities. The sampling population consists of 40 institutions. The research team used a

7x3x2 disproportionate, stratified random sampling design to select a representative sample of programs using three strata: discipline, accreditation review status (early, required, deferred)¹⁴, and NSF Engineering Education Coalition membership (yes or no)¹⁵.

All tenure track faculty and all seniors in the relevant disciplines were surveyed. Programs with very low faculty response ($n < 5$ and response rate $< 25\%$) or low student response ($< 20\%$) were eliminated from the original sample in order to maximize the validity of program-level parameters. The resulting sample includes 1,037 faculty members (42% response rate) and 3,338 students (34% response rate), representing 142 engineering programs on 39 campuses from a variety of institutional types (as defined by Carnegie Classification, 2001). In order to maximize the generalizability of the data to the larger population, the faculty cases were weighted by gender, discipline, and NSF coalition; and the student cases by gender and discipline. The student and faculty sample distributions were very similar to the population, and the application of survey further improved the representativeness of the sample. The majority of student respondents were in electrical, mechanical, civil, and chemical engineering programs. The majority was male and attended public, research institutions. Faculty were similarly distributed. Table 1 shows the distribution of faculty respondents in the sample with respect to years of industry experience. Half of the faculty respondents had 3 or more years of industry experience. The distributions across programs were similar to the overall distribution.

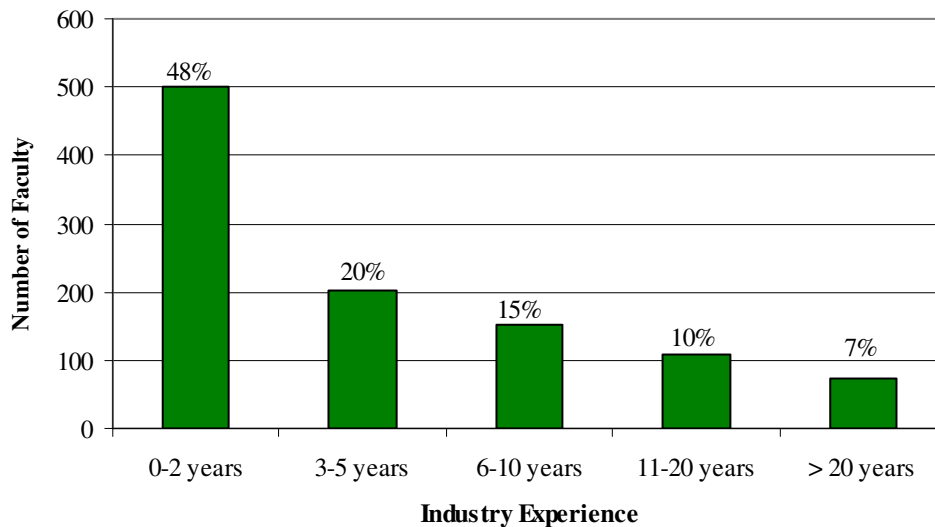


Figure 1. Years of Industry Experience Held by Faculty Respondents.

The primary independent variable was the proportion of a program's faculty members with three or more years of industry experience. The outcome variables were the amount of time students spent in internships or cooperative education (hereafter referred to as “coop”), non-required design competitions, or professional societies’ student chapters. Covariates included student gender, precollege ability, and program discipline.

Because the study relies on multi-level data, we followed Ethington's¹⁶ and Raudenbusch and Bryk's¹⁷ recommendations and used a two-level, hierarchical linear model (HLM) with students nested within programs. These procedures, allow the assignment of variance to both levels of data and the correct use of students as the unit of analysis. This analysis determines the degree to which the student co-curricular experiences are predicted by faculty industry experience and the degree to which they are predicted by student pre-college characteristics identifying the variance explained by each level. In most studies of students' college experiences, individual student characteristics and the characteristics of their academic program are confounded because students cannot be randomly assigned to majors. With students as the unit of analysis, traditional linear regression techniques require that all higher-order variables be disaggregated to the individual student level. This approach results in students in the same program having the same value on all program-level variables, violating the independence of observations assumption of most linear models. HLM (also known as multilevel modeling) has advantages over traditional regression techniques for this type of analysis because it recognizes the dependence of student-level variables and treats groups in the sample as a random sample from a population of groups, allowing for inference to the population. Detailed presentations of HLM are available in Raudenbush & Bryk.¹⁷

The analyses for the multilevel model were conducted using the Hierarchical Linear and Non-Linear Modeling (Version 6.04) statistical package.¹⁸ Although institutional characteristics such as institution type and wealth introduce a potential third level (with programs nested within it), their effects on students have been demonstrated to be too distant from student experiences to have strong direct effects on student outcomes.^{7,8} For this reason institutional-level variables were not included in the model. A two-level model was tested for each of the three co-curricular activities of interest.

Because HLM is based on linear regression, it remains the case that the intercept is the value of Y when X is equal to zero. For many variables (e.g., SAT scores) values of zero do not naturally occur. By centering variables like these around their grand mean, their interpretation is clearer. Following standard HLM conventions, the level-one variables, SAT and high school GPA) were centered on the ground mean.

A one-way ANOVA with random effects provided the preliminary model (see appendix for all model specifications). This model addresses the initial question of whether engineering programs vary significantly in their mean student co-curricular experiences. Next, the variable of primary interest (proportion of program faculty with three or more years of industry experience) was introduced as the level-two predictor in the model. In the final model, program and student-level controls were added to reduce the unexplained variance in the model. These controls included the level-one variables gender, total SAT score, and high school GPA and a level-two control variable, engineering discipline. Given significant level-two (program) differences, this model is used to test whether there is a relationship between the experience of program faculty and individual student co-curricular participation, net of the influence of other important student and disciplinary characteristics.

Findings

The initial one-way ANOVA with random effects indicated statistically significant program-level variation in the three student co-curricular experiences -- internship/coop, design competition, and professional society participation (Table 1). Between-program differences accounted for twelve percent of the variance in internships and coops, four percent in design competition participation, and five percent in professional society participation. Although these relatively low intraclass correlation coefficients (ICC) suggest that a two-level model may not be the best approach despite the significant program-level variation, some analysts argue that over-reliance on the size of the ICC can lead to the premature abandonment of a multilevel model. In some cases, the addition of predictor variables into the model can result in higher group dependence than might be expected from a low ICC in the initial model¹⁹. Because of this possibility, and because of the multilevel nature of the relationships proposed in the conceptual framework, model building continued.

Table 1. Results from the One-Way ANOVA Model.

<i>Fixed Effect</i>	<i>Coefficient</i>	<i>Standard Error</i>		
Average program mean, γ_{00}				
Internship/Coop	2.49	.05		
Design Comp.	1.71	.03		
Prof. Society	2.09	.03		
<i>Variance Component</i>				
<i>Random Effect</i>	<i>Variance Component</i>	<i>df</i>	χ^2	<i>p Value</i>
Program mean, u_{0j}				
Internship/Coop	.25	139	553.37	.000
Design Comp.	.04	139	258.30	.000
Prof. Society	.06	139	318.35	.000
Level-1 effect, r_{ij}				
Internship/Coop	1.39			
Design Comp.	1.20			
Prof. Society	.99			

When faculty industry experience was added as a predictor, program-level variance remained significant, but the influence of faculty experience was positive and significant only on design competition experience ($p = .026$), explaining seven percent of the between-program variance. This model indicates that students in programs with a high proportion of faculty with three or more years of industry experience are more active in design competitions, but do not spend significantly more time in internships or coops, or in professional society student chapters than their peers in programs with faculty having more limited industry experience. This intermediate model, however did not control for differences between students and engineering disciplines, leaving open the alternate hypothesis that student characteristics, rather than faculty experience, may explain program differences.

When discipline, student gender, and student ability were added as controls to the design competition model, the overall design competition model improved significantly ($\chi^2 = 107.56$, $df = 9$; $p < .001$). Significant variation remained between programs, and industry experience was a

significant predictor of participation ($p = .01$). The addition of the control variables reduced the unexplained variance at the student-level by only one percent, but reduced it by 20 percent at the program-level. These results suggest that these individual student characteristics and program discipline make small contributions to differences in student experiences within schools, but that they have a more substantial impact on the differences in students' level of co-curricular activity across programs. As can be seen in Table 2, gender was not a significant predictor on any of the outcomes, and pre-college ability was a significant influence only on participation in internships and cooperative education experiences.

Table 2. Final Model Random Effects (df=99).

<i>Random Effect</i>	<i>Variance Component</i>	χ^2	<i>p Value</i>
Internship/Coop			
Program mean, u_{0j}	.22	126.24	.03
Gender, u_{1j}	.02	84.21	NS
SAT, u_{2j}	.00	121.38	.06
High School GPA, u_{3j}	.05	125.26	.04
Level-1 effect, r_{ij}	1.86		
Design Competition			
Program mean, u_{0j}	.03	120.13	.07
Gender, u_{1j}	.04	102.77	NS
SAT, u_{2j}	.00	85.82	NS
High School GPA, u_{3j}	.02	101.84	NS
Level-1 effect, r_{ij}	1.18		
Professional Society			
Program mean, u_{0j}	.03	128.22	.03
Gender, u_{1j}	.03	113.48	NS
SAT, u_{2j}	.00	99.29	NS
High School GPA, u_{3j}	.01	92.22	NS
Level-1 effect, r_{ij}	.97		

Note: NS = not significant at the .10-level.

Limitations

Like all studies, this one is limited in several respects. First, given the post hoc and cross-sectional design, threats to internal validity exist, and no causal connections can be inferred. Manipulating the level of program faculty experience and randomly assigning students to these programs in order to demonstrate causality²⁰ was impossible. In addition, despite the use of a number of control variables, respondents may still not be functionally equivalent, and weighting the data to improve sample representativeness may have obscured real differences between respondents and non-respondents.

Second, like all conceptual frameworks, the model underlying this study is a simplification of a very complex set of conditions and processes. Moreover, in order to develop a parsimonious and statistically powerful model, a number of potentially influential variables, such as student race/ethnicity, student socioeconomic status, and institution size and wealth, were not included. Preliminary regression analyses, as well as prior analyses using this dataset,²¹ however, suggest that these are not important predictors of students' co-curricular experiences.

Third, although the study tested a widespread assumption about the value of faculty members' industry experience, the data were not gathered for this purpose. Consequently, we were unable to account for alternative hypotheses about the factors that influence the level of student participation in selected out-of-class engineering-related experiences. It may be, for example, that some students are may be more inclined than others to such participation and that those students were not distributed randomly across programs.

Discussion

Program-level variance in student co-curricular participation, net of student precollege ability and gender, demonstrates that programs do vary in the level at which their students participate in internships and coops, design competitions, and the student chapters of professional societies. This finding, in and of itself, is an important one. It demonstrates that programs, by whatever mechanism, have an active role in promoting participation in important co-curricular learning experiences. We hypothesized that one component of that mechanism might be faculty members' industry experience and that such experience would have a positive influence on students' educational experiences. We expected that the proportion of faculty with such experience would significantly and positively influence student participation in a variety of co-curricular activities. Specifically, we explored three co-curricular activities closely related to developing applied and professional engineering skills. Because undergraduate design competitions, internships and coops, and campus-based professional societies focus largely on developing workplace skills and employment opportunities, we hypothesized that faculty with substantial industry experience would be stronger supporters of student participation in these activities than their more academically inclined colleagues because they would place a higher value on preparing students to apply what they are learning in class and, thereby, increase the likelihood of students' employment upon graduation, as opposed to preparing them for graduate education.

If, as Dym and his colleagues'¹¹ suggest, the key purpose of an undergraduate engineering education is the ability to design a product or process, then the influence of faculty characteristics on student participation in design projects is a particularly important consideration for engineering programs. Despite the increasing emphasis on incorporating design throughout the engineering curriculum, however, many programs address design in only one or two courses and often not until the final year of study. While recognizing the importance of design education, engineering programs are faced with a constant barrage of topics that *should* be incorporated into the curriculum (see for example, *The Engineer of 2020*,²² *Rising above the Gathering Storm*²³ and ABET's EC2000 criteria²⁴). In an overloaded four-year curriculum, co-curricular design activities can provide an additional important learning opportunity for students.

Our findings suggest that as the proportion of faculty in a program with industry experience increases, so does the amount of time students spend in these activities. Precisely why this relation exists remains to be explored. It may be that these faculty members encourage participation more than their non-industry counterparts, or it may be that programs with a large proportion of such faculty tend to offer more opportunities for students to engage in such activities. While the reason(s) for this relationship deserves further attention, the implication remains. Faculty members' industry experience can positively effect student participation in

design competitions and activities and should be a consideration in the recruitment of new faculty.

Contrary to our expectations, however, the model did not support the hypothesis that faculty industry experience would also influence student participation in internships and cooperative education or in the student chapters of professional societies. It may be that involvement in internships and coop experiences is more significantly shaped by a program's curricular requirements than by faculty members' characteristics. Alternatively, and regardless of the presence or absence of an industry background, faculty members may promote these opportunities to about the same degree. It is also possible that other circumstances not incorporated into this study, such as the presence of a dedicated internship/coop office or strong programmatic ties to industry through an alumni council, advisory board, or other outlet are the critical determinants of student participation in an academic work experience. The availability of such opportunities varies widely across institutions, as may program support for student involvement in them. While faculty industry experience was not demonstrated to be a direct influence on student involvement in internship/coop or society chapter activities, it may influence student participation indirectly by affecting program-level attention to and support for such activities.

Conclusions

Although student experience-and-learning links are well established, institutions still struggle to identify the most educationally powerful experiences and to find ways to capitalize on those experiences to increase students' engagement and learning. The challenge is particularly acute in professional fields, like engineering, which significantly and immediately influence the nation's workforce and its global economic and technological competitiveness. National reports^{22,23} suggest that engineering graduates still lack some of the skills needed now and in the future. The problem, some say, is that today's students are taught by faculty members with little or no industry experience.

This study examined that proposition. Although not conclusive, the findings suggest that the collective industry experience of a program's faculty does, indeed, influence student participation in at least one important co-curricular activity. Compared to students in programs with faculty having limited industry experience and net of individual characteristics, students in programs with a higher proportion of faculty with industry experience reported spending significantly more time participating in out-of-class design activities. The evidence did not, however, confirm the expectation that students in such programs would also spend more time in internships and cooperative education or be more involved in student chapters of professional societies. It appears that organizational hiring practices and policies are at least one means of shaping the kinds of co-curricular experiences students have and, at least indirectly, influencing student learning.

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Appendix

Model 1: One-way ANOVA with random effects.

$$Y_{ij} = \gamma_{00} + u_{0j} + r_{ij}$$

Model 2: Tests the direct effect of faculty experience variable on outcomes.

$$Y_{ij} = \gamma_{00} + \gamma_{01} * Experience_j + u_{0j} + r_{ij}$$

Model 3: Introduces the level-one and level-two control variables (gender, SAT, high school GPA, and engineering discipline) to the model.

$$\begin{aligned} Y_{ij} = & \gamma_{00} + \gamma_{01} * Aerospace_j + \gamma_{02} * Chemical_j + \gamma_{03} * Civil_j + \gamma_{04} * Computer_j + \\ & \gamma_{05} * Industrial_j + \gamma_{06} * Mechanical_j + \gamma_{07} * Experience_j + \gamma_{10} * Gender_{ij} + \gamma_{11} * \\ & Aerospace_j * Gender_{ij} + \gamma_{12} * Chemical_j * Gender_{ij} + \gamma_{13} * Civil_j * Gender_{ij} + \\ & \gamma_{14} * Computer_j * Gender_{ij} + \gamma_{15} * Industrial_j * Gender_{ij} + \gamma_{16} * Mechanical_j \\ & * Gender_{ij} + \gamma_{17} * Experience_j * Gender_{ij} + \gamma_{20} * (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{21} * \\ & Aerospace_j * (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{22} * Chemical_j * (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{23} * \\ & Civil_j * (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{24} * Computer_j * (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{25} * Industrial_j * \\ & (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{26} * Mechanical_j * (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{27} * Experience_j * \\ & (SAT_{ij} - \overline{SAT}_{..}) + \gamma_{30} * (GPA_{ij} - \overline{GPA}_{..}) + \gamma_{31} * Aerospace_j * (GPA_{ij} - \overline{GPA}_{..}) \\ & + \gamma_{32} * Chemical_j * (GPA_{ij} - \overline{GPA}_{..}) + \gamma_{33} * Civil_j * (GPA_{ij} - \overline{GPA}_{..}) + \gamma_{34} * \\ & Computer_j * (GPA_{ij} - \overline{GPA}_{..}) + \gamma_{35} * Industrial_j * (GPA_{ij} - \overline{GPA}_{..}) + \gamma_{36} * \\ & Mechanical_j * (GPA_{ij} - \overline{GPA}_{..}) + \gamma_{37} * Experience_j * (GPA_{ij} - \overline{GPA}_{..}) + u_{0j} \\ & + u_{1j} * Gender_{ij} + u_{2j} * (SAT_{ij} - \overline{SAT}_{..}) + u_{3j} * (GPA_{ij} - \overline{GPA}_{..}) + r_{ij} \end{aligned}$$