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An Examination of the Relationship Between Intellectual Development and Learning Preferences in Electrical and Computer Engineering (Ongoing)

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Abstract

Engineering educators have used the evaluation of students' learning preferences as a way to improve academic performance and the overall classroom experience. This paper discusses an ongoing study that examines the link between the learning preferences and the intellectual development of engineering students. It further seeks to examine to what extent do students with particular learning preferences undergo a higher degree of intellectual development through an engineering curriculum. Electrical and computer engineering students at a large Midwestern university completed inventories with respect to intellectual development (Learning Environment Preference) and learning styles (Index of Learning Styles) in order to establish their level of intellectual development and their learning style. Preliminary results show that specific learning styles achieve higher intellectual development assessment scores and the degree of preference for a learning style is a factor in the intellectual development as it relates to the assessment scores.

I. Introduction

Over the past twenty years, engineering educators have noticed a trend within engineering as a whole: students are not progressing as much as they should with respect to their intellectual development before graduating [1]. There has been research with respect to how experimental courses can improve this deficit[2], [3], but very little published examining what can be done with respect to current engineering courses. One idea that is being used by some engineering educators that seems to be having success improving student's grades is the identification of students' learning style preferences and tailoring aspects of the class to them[4], [5]. Although there have been studies giving an overview on engineering students with respect to intellectual development and learning styles[1], [6–9], there has been little published work trying to find an overlap between the two. This paper examines an ongoing study that is investigating if the learning style of engineering students has an effect on the intellectual development. The paper will review intellectual development and learning styles, explain the methodology of the experiment, present some preliminary results, and discuss possible future directions of the research.

II. Rationale and Model Descriptions

Why even investigate a potential link between intellectual development and learning styles? A common goal of engineering educators is to demonstrate that graduates have the ability to solve current engineering issues, which include ill-defined problems[2]. In order to acquire this ability, most students must undergo some form of intellectual development during their college career. There are multiple perspectives on how intellectual development, defined in this paper as the progression of one's views of knowledge [10], [11], can be evaluated in the overall learning process[12]. While most courses tend to focus on teaching technical knowledge, some engineering educators suggest that courses should focus on intellectually developing students because it has the potential to impact how well one can solve ill-defined problems[13–

16]. Since intellectual development deals with views on knowledge, other concepts that deal with one's interactions with knowledge may have some influence on how much intellectual development an individual undergoes. One such concept is learning styles, the types of knowledge one concentrates on and how they like to perceive new knowledge[17].

Intellectual Development Models

In order to evaluate the link between the intellectual development and the learning style of engineering students, we first needed to choose models that would best describe engineering students. Almost all research in intellectual development models is derived from Piaget's work and his work on genetic epistemology[18]. Early intellectual development research findings suggested that people have domain-general views of knowledge and subsequent models were based on this finding[12]. Though a majority of current intellectual development research is now looking at domain-specific and domain-general/domain-specific hybrid models[18–21], most published engineering education research with respect to intellectual development uses domain-general intellectual models[1], [3], [6], [13]. For this study, we investigated three of the best-known domain-general intellectual development models. Descriptions of each model are given below.

A. Reflective Judgment Model

For almost 30 years, Dr. Karen Kitchener and Dr. Patricia King have been researching the development of epistemic cognition and its relationship to the ability for students to solve open-ended problems[22]. Their research produced seven sets of assumptions on knowledge and how to obtain it. These sets became the stages in their Reflective Judgment (RJ) model[23]. The seven stages are divided into three group described below.

- Pre-reflective (Stages 1-3) – In these stages, knowledge is obtained only from authorities or firsthand experience and that knowledge is "known" to be correct.
- Quasi-reflective (Stages 4-5) – Individuals begin to recognize that knowledge contains some uncertainty due to missing information. They cannot make their own conclusions on knowledge based on evidence.
- Reflective (Stages 6-7) – Individuals recognize that knowledge claims cannot be made with complete certainty but can choose "the one that makes the most sense" based on their own standards. Knowledge can be revisited and changed if new evidence is brought to light.

B. Epistemological Reflection Model

Research in intellectual development has primarily dealt with populations consisting of undergraduates. Dr. Marcia Baxter-Magolda wanted to look at the intellectual development of individuals in college as well as when they graduated. The results of the interviews led to a new model of intellectual development known as the Epistemological Reflection Model (ERM)[24]. ERM consists of four ways to perceive knowledge that are explained below.

- Absolute Knowing – Individuals at this level see all knowledge as being either right or wrong and in the possession of an expert such as a professor. Most learners are usually at this level at the beginning of their collegiate career.
- Transitional Knowing – Individuals at this level understand that some knowledge is uncertain and further research is needed in order to find an answer. Individuals at this level spend a majority of their time developing this skill or learning how to access other people's perspective. Many learners are at this stage during the middle of their collegiate career.
- Independent Knowing – Individuals view most knowledge as being uncertain. They begin to think for themselves and make decisions based on their own understandings and beliefs. Some students reach this level toward the end of college.
- Contextual Knowing – Individuals generate knowledge based on the context on which evidence supporting the knowledge is used. Very few students obtain this level before they graduate. [24]

C. Scheme of Intellectual and Ethical Development

A team of Harvard researchers led by Dr. William Perry conducted a series of interviews with students at Harvard and Radcliffe College about their education experience. From these interviews, the team noticed a natural progression of thinking of the students. From this progression, Perry formed nine stages which became the Perry Scheme of Intellectual and Ethical Development (SIED)[25]. The stages were grouped into four groups that are described below.

- Dualism (Stages 1-2) - Individuals believe that all knowledge falls into two categories, right or wrong. They tend to view authorities as all-knowing source.
- Multiplicity (Stages 3-4) – Individuals begin to recognize knowledge falls into the known and unknown categories. They also begin to recognize their own role determining the validity of knowledge.
- Relativism (Stages 5-6) – Individuals complete the transition to the view that knowledge is relativistic with a small number of dualistic exceptions. They also realize they are an authority with respect to generating meaning of knowledge.
- Commitment (Stages 7-9) – Individuals' development shifts from intellectual to ethical. In these stages, individuals begin to recognize, develop, and refine commitments to paths that may have several credible alternatives [26].

For this study, we chose Perry's SIED model because of its use in other research of the intellectual development of engineering students[1–3], [6].

Learning Style Models

Though learning styles have been discussed for centuries, the development of models has been a focus of educational psychologist for the past 50 years[27]. As time has progressed, learning style models have ventured out of psychology and into various fields including engineering. In planning the study, we examined two learning models that have been used in a lot of engineering research.

A. Myers-Briggs Psychological Types

The Myers-Briggs Psychological Types are a model of psychological types developed by Dr. Katherine Briggs and Dr. Isabel Briggs Myers[28]. They derived their model from a theory of psychological types created by Dr. C.G. Jung. After years of observation, Jung theorized that there were two types of people (extroverts and introverts) who use two mental functions (perceiving and judging) in a dominant and auxiliary role to interact with their surroundings[29]. These interactions correspond to the way the individual would like environment to present information for understanding. Descriptions of the types of people and their mental functions are given below.

- Extrovert/Introvert – Corresponds to an individual's processing function. Extroverts focus their energy toward things in their outside environment while introverts focus their energy on things in their internal environment.
- Sensing/Intuitive – Corresponds to an individual's perceiving function, the way an individual becomes aware of ideas and gathers information. Sensing individuals prefer to perceive knowledge through the five senses. Intuitive learners prefer to perceive knowledge through abstract methods.
- Thinking/Feeling – Corresponds to an individual's judging function, the way people form conclusion based on their perceptions. Thinking learners develop answers based on logical connections between facts. Feeling learners come to their conclusion based on their personal values and the values of the issues being evaluated.
- Judging/Perceiving – Corresponds to individual's attitude toward the outside world. This dichotomy also specifies which mental function is dominant and which has an auxiliary role[28].

B. Felder and Silverman's Model of Learning Styles (FSMLS)

In 1988, Dr. Richard Felder and Dr. Linda Silverman introduced a model of learning styles, which we refer to as FSMLS, to explain what factors of the learning process were important to engineers[30]. The model consisted of components of existing learning styles models such as Jung and Kolb as well as their some original additions[17]. Descriptions of the dimensions of the model are listed below.

- Visual/Verbal - Visual learners are those who like to receive information through images, diagrams, symbols, etc. Verbal learners prefer verbal explanations and written notes to obtain information.
- Sequential/Global – Sequential learners like when knowledge is presented in a step-by-step manner. Global learners want knowledge to be given in a broad, potentially complex manner that allows them to fill in the blanks through "ah-ha" moments.
- Active/Reflective – Active learners acquire knowledge through hands-on experience and trial and error. Reflective learners tend to take knowledge in and process it through internal reflection.
- Sensing/Intuitive – Sensing learners like knowledge to be presented as facts and experimentation. Intuitive learned like when knowledge is presents as theories and principles. [30]

We chose FSMLS for our experiment because Felder and Silverman designed their learning styles model specifically for engineering students.

III. Methodology

This paper is part of a larger study that is examining the impact of various characteristics of engineering students on their overall intellectual development. For this paper, we are investigating the impact of an individual's learning preferences on their intellectual development.

Participants

Currently, 44 electrical/computer engineering students at a large Midwestern University are participating in the study. The students' classifications range from sophomore to senior because students do not declare their specific engineering major until their sophomore year. A summary of participants with respect to classification is given in Table 1.

Table 1: Participant breakdown with respect to their classification at the time of participation

Classification	n
Sophomore	10
Junior	17
Senior	17

Inventories

To assess a participants' location on Perry's SIED, we used the Learning Environment Preferences (LEP) inventory created by Dr. William Moore. The LEP is a 65-item Likert-scale inventory that has individuals express the importance of various aspects of classroom across five domains. Participants then rank which three aspects they deem the most important for each domain. Evaluators correspond these rankings to levels on Perry's SIED and calculate an individual's Cognitive Complexity Index (CCI) score. The range of this score is from 200 (dualism) to 500 (relativism). Though we can create score ranges to relate a CCI score with an individual's position on the Perry's SIED, it is suggested to use it as a general indicator of intellectual development. This is because the CCI incorporates the responses across positions 2-5[31]. We chose the LEP inventory because of its reliability[32] and cost effectiveness.

For FSMLS, Felder and Dr. Barbara Solomon created the Inventory of Learning Styles (ILS) inventory to assess one's learning style[33]. The inventory has been shown to be reliable [7], [34], [35], and was designed with engineering students as its target audience. In addition to the actual learning style, ILS can also determine degree of preference for every dimension of an individual's learning style. A breakdown of how the results of the ILS inventory correspond to the degree of preference is shown in Table 2.

Table 2: Degree of preference with respect to ILS score ranges.

Score Range	Degree of Preference
1-3	Mild
5-7	Moderate
9-11	Strong

We also created a background survey to collect information on factors that may have had an impact on a participant's intellectual development. Examples include domestic/international students, number of internships and co-ops, military service, study abroad experiences, etc.

Procedure

Participants are administered the background survey, the LEP inventory, and the ILS in a computer lab setting. The responses of the background survey and the LEP inventory are stored for later analysis while the responses of the ILS inventory are evaluated and the results are recorded for each participant. The participant's responses on the LEP inventory are transferred to the Center for the Study of Intellectual Development for analysis. Once the LEP results are returned, a profile for each participant is generated consisting of their CCI score, their ILS results, and the information collected from the background survey. For this paper, we are only using participant's classification from the background survey information. The profiles are then compared to find links between learning styles and intellectual development.

Results

For each classification, we divided the participants into two sets of groups to being to investigate effects of learning styles on intellectual development. The first grouping is based on the participants' preferred learning style as indicated by the ILS results. The second grouping is the degree of their preference within a learning styles dichotomy. We placed participants into one of three groups: a moderate or strong preference for one side of the dichotomy, a mild preference for either side of the dichotomy, or a moderate or strong preference for the other side. We calculated the average CCI for each group and if 4 or more participants fell into a group, we found the effect size between the different groups within and across classification to determine the impact the learning style, the degree of preference, or classification had on CCI scores. We did this for each of the four learning style dichotomies and presented our findings below.

Active/Reflexive

Tables 3 and 4 shows the CCI scores for students with respect to the active/reflexive dichotomy. We see that participants with a reflexive preference begin their engineering academic careers with higher CCI scores than their active counterparts, (M ± S.D) 348.7 ± 36.2 vs. 293.5 ± 32.9. As they progress, the reflexive learners continued to outscore their active counterparts (347.6 ± 31.3 vs. 320.6 ± 54.5 for juniors and 346.0 ± 44.7 vs. 326.6 ± 42.7 for seniors), but the gap in CCI scores decreased. This was due to the improvement in active learners intellectual development from their sophomore to their senior year. The effect size of being a junior with an active learning preference instead of a sophomore with the same persuasion ($d = 0.55$) suggests a moderate improvement of intellectual development. The CCI scores also suggests there is some intellectual development for active learning seniors with respect to their junior counterparts, but it seems to be insignificant ($d = 0.12$). As for reflexive learners, their CCI scores that they undergo very little development from their sophomore year to their senior year.

Table 3: Breakdown of participants with respect to active/reflexive dichotomy

Classification	Type of Learner	N	CCI Mean	Standard Dev.
Sophomore	Active	4	293.5	32.9
	Reflexive	6	348.7	36.1
Junior	Active	8	320.6	54.5
	Reflexive	9	347.6	31.3
Senior	Active	8	326.6	42.7
	Reflexive	9	346	44.7

When we shift the focus to degree of preference, we see that learners with a stronger preference for reflexive learning (350.8 ± 43.4) begin their academic careers with higher CCI scores that those who have a mild leaning toward either learning preference (316.0 ± 40.8). The effect size (d = 0.83) suggests that this is a significant difference. We currently do not have enough participants to make any claims about sophomores who have a stronger active preference. When we shift to participants in their junior year, we see improvement in the CCI scores for participants with mild preferences (332.3 ± 48.3) while the CCI scores learners with a stronger reflexive preference (348.5 ± 34.1) remains about the same. While learners with a stronger reflexive preference still outscore those learners with a mild preference, the effect of having a stronger reflexive preference (d = 0.36) for juniors has now become small. We also see that the effect of being a junior instead of a sophomore for participants with a mild preference (d = 0.35) is a mild one. Senior participants with a mild preference surpass their counterparts who have a stronger reflexive preference (341.4 ± 29.1 vs. 328.0 ± 44.0). Also, participants who have a strong active preference have the highest average of the three (342.0 ± 57.5). When we compare effects of each degree of preference, we see that effects are either small (d = 0.35 for mild preference vs. stronger reflexive preference, d = 0.27 for stronger active preference vs. stronger reflexive preference) or insignificant (d = 0.01 for stronger active preferences vs. mild preference).

Table 4: Breakdown of participants with respect to degree of preference across the active/reflexive dichotomy

Classification	Degree of Pref.	n	Mean	Standard Dev.
Sophomore	Mod/Str Active	1	283.0	-
	Mild	5	316.0	40.8
	Mod/Str Reflexive	4	350.8	43.4
Junior	Mod/Str Active	3	294.7	6.8
	Mild	10	332.3	48.3
	Mod/Str Reflexive	4	348.5	34.1
Senior	Mod/Str Active	6	342.0	57.5
	Mild	5	341.4	29.1
	Mod/Str Reflexive	6	328.0	44.0

Sensing/Intuitive

The results for the participants with respect to the sensing/intuitive dimension are shown in Tables 5 and 6. Sophomore participants with a sensing preference scored better on the LEP (339.8 ± 38.8) than those with an intuitive preference (306.8 ± 48.1). These results suggest that having a sensing preference compared to an intuitive preference (d = 0.77) has a moderate, positive effect on CCI scores for sophomores. For the junior participants, the CCI scores of sensing learners decreased (314.9 ± 39.5) and improved for the intuitive learners (363.4 ± 36.5). These scores suggest that there is a large, positive effect in being an intuitive learner instead of a sensing learner for juniors (d = 1.27). While the effect of being a junior for intuitive learners compared to being a sophomore was large (d = 1.39), there was a moderate, negative effect (d = -0.64) of being a junior with a sensing preference compared to a sophomore. Senior participants with an intuitive preference also outscored their sensing counterparts (374.5 ± 40.4 vs. 316.4 ± 30.1). Being a senior had a small effect on CCI scores for those with an intuitive preference (d = 0.29) while the effect was insignificant (d = 0.04) for those with a sensing preference.

Table 5: Breakdown of participants with respect to sensing/intuitive dichotomy

Classification	Type of Learner	N	CCI Mean	Standard Dev.
Sophomore	Sensing	6	339.8	38.8
	Intuitive	4	306.8	48.1
Junior	Sensing	10	314.9	39.5
	Intuitive	7	363.4	36.5
Senior	Sensing	11	316.4	30.1
	Intuitive	6	374.5	40.4

As for degree of preference, we start with the juniors since we currently do not have enough data points to do any comparisons between different degrees of preference for the sophomore participants. Juniors with a mild preference averaged a higher score (357.1 ± 34.1) than those with a stronger sensing preference (297.5 ± 31.0). Further analysis showed that having a mild preference has a very large effect (d= 1.82) on CCI scores compared to those with a stronger sensing preference. For the senior participants, those with a mild preference continue to outscore their counterparts who have a stronger preference towards sensing (354.2 ± 43.8 vs. 316.1 ± 35.6) causing us to find a large effect on CCI scores (d = 0.96). When we compare across classifications, we see that being a junior instead of a sophomore has a moderate effect on CCI scores (d = 0.60) for participants with a mild preference. Being a senior has a medium effect on CCI scores (d = 0.55) for participant with a stronger sensing preference and a negligible negative effect (d= -0.08) for those with a mild preference compared to their junior equivalents.

Table 6: Breakdown of participants with respect to degree of preference across the sensing/intuitive dichotomy

Classification	Degree of Pref.	n	Mean	Standard Dev.
Sophomore	Mod/Str Sensing	1	333.0	-
	Mild	8	334.8	40.3
	Mod/Str Intuitive	1	255.0	-
Junior	Mod/Str Sensing	6	297.5	31.0
	Mild	8	357.1	34.1
	Mod/Str Intuitive	3	350.3	53.5
Senior	Mod/Str Sensing	8	316.1	35.6
	Mild	8	354.2	43.8
	Mod/Str Intuitive	3	357.7	51.7

Visual/Verbal

There are not enough verbal learners, as seen in Tables 7 and 8, to make a meaningful comparison between visual and verbal learners for juniors and seniors at this time. We do see that visual learners do have some improvement in average CCI score between sophomore and junior year (324.3 ± 49.5 vs. 335.7 ± 47.0). The improvement almost complete disappears when we move on to the senior participants (326.6 ± 45.7). The effect sizes between classifications for visual learners (juniors vs. sophomores: d = 0.24, seniors vs. juniors: d = -0.03) suggest the magnitudes of these changes are small.

Table 7: Breakdown of participants with respect to visual/verbal dichotomy

Classification	Type of Learner	N	Mean	Standard Dev.
Sophomore	Visual	6	324.3	49.5
	Verbal	4	330	39.8
Junior	Visual	15	335.7	47.0
	Verbal	2	329	26.9
Senior	Visual	14	326.6	45.7
	Verbal	3	346	40.3

Junior participants with a mild preference had a higher average CCI score (343.2 ± 35.1) than those with a stronger visual preference (330.4 ± 49.9). The effect size (d = 0.28) suggests that having a mild preference has a small impact on gains intellectual development compared to having a stronger visual preference. The opposite occurs with respect to CCI averages for the senior participants. Seniors with stronger visual preference outscored those with a mild preference (345.3 ± 44.0 vs. 316.8 ± 39.4) causing us to see that having a mild preference has a negative effect (d = -0.66) on CCI scores. Compared to their junior counterparts, being a senior with a stronger visual preference has a small effect (d = 0.32) while being a senior with a mild preference has a moderate, negative effect (d = -0.71).

Table 8: Breakdown of participants with respect to degree of preference across the visual/verbal dichotomy.

Classification	Degree of Pref.	N	Mean	Standard Dev.
Sophomore	Mod/Str Visual	5	323.2	55.3
	Mild	3	329.0	4.6
	Mod/Str Verbal	2	331.5	68.6
Junior	Mod/Str Visual	11	330.4	49.9
	Mild	6	343.2	35.1
	Mod/Str Verbal	0	-	-
Senior	Mod/Str Visual	8	345.3	44.0
	Mild	8	316.8	39.4
	Mod/Str Verbal	0	-	-

Sequential/Global

Tables 9 and 10 show how the participants did with respect to the sequential/global dichotomy. When we examine sequential learners across classifications, we see a gradual decline in CCI scores. Sophomore sequential learners averaged a CCI score of 347.3 ± 50.0, juniors averaged 333.0 ± 44.8, and seniors averaged 320.1 ± 32.8. The negative effect sizes (d = -0.31 for juniors compared to sophomores and seniors compared to juniors) suggest that progressing through an ECE program as a sequential learner has a negative effect on intellectual development. Global learners seem to progress as the sophomores averaged 312.8 ± 36.7 while senior global learners averaged 351.8 ± 48.2 on the LEP. Examining the two groups within a classification, we see that being a sequential learner has a large positive effect on CCI scores (d = 0.81) for sophomores but has a moderate negative effect on CCI scores for seniors (d = -0.76).

Table 9: Breakdown of participants with respect to sequential/global dichotomy

Classification	Type of Learner	n	Mean	Standard Dev.
Sophomore	Sequential	4	347.3	50.0
	Global	6	312.8	36.7
Junior	Sequential	14	333.0	44.8
	Global	3	343.7	51.6
Senior	Sequential	8	320.1	32.8
	Global	9	351.8	48.2

Looking at degree of preference, the only category we can currently analyze across classifications is the learners with a mild preference. The average CCI score improved from sophomores (327.0 ± 59.8) to juniors (332.1 ± 46.6) to seniors (340.0 ± 49.6), as one would expect. The gains however were relatively small, which suggests that classification has a little effect on intellectual development for learners with a mild preference. The effect sizes for juniors compared to sophomores (d = 0.10) and seniors compared to juniors (d = 0.17) support this view. If we switch focus to look at different degrees of preference within the same classification, we see some interesting trends. For sophomores, there is little difference between learners with a mild preference and those with a stronger preference towards global (324.5 ± 30.2). This is further shown when we look at the effect size (d = 0.05) with respect to the learners with a mild preference. When we examine the senior participants, the learners with a stronger global preference (350.0 ± 44.9) outperform those with a mild preference and those with stronger sequential preference (316.8 ± 27.4). There is effect of having a mild preference compared to a stronger global preference (d = -0.20) is minor and negative, but is moderate and positive when compared to having a stronger sequential preference (d = 0.52).

Table 10: Breakdown of participants with respect to degree of preference across the sequential/global dichotomy.

Classification	Degree of Pref.	n	Mean	Standard Dev.
Sophomore	Mod/Str Sequential	1	333.0	-
	Mild	5	327.0	59.8
	Mod/Str Global	4	324.5	30.2
Junior	Mod/Str Sequential	2	348.0	53.7
	Mild	14	332.1	46.6
	Mod/Str Global	1	348.0	-
Senior	Mod/Str Sequential	4	316.8	27.4
	Mild	9	340.0	49.6
	Mod/Str Global	4	350.0	44.9

IV. Analysis and Future Work

The initial results of the study show some promising results with respect to their being a link between learning styles and intellectual development. Three of the four dichotomies (active/reflexive, sensing/intuitive, and sequential/global) suggest that having a particular type of learning preference leads to some significant gains in intellectual development and that most of the gains occur between the sophomore and junior year. Active learners seem to undergo bigger changes in intellectual development, but do not progress as far as their reflexive counterparts. Learners with a sensing preference start out more advanced than those with an intuitive preference, but are surpassed because of the gains of intuitive learners and the regression of sensing learners by the time they graduate. This is also true from sequential learners with respect to global learners. One possible explanation for the regression of sensing and sequential learners is that they are retreating in Perry's model because the classroom environment has changed from what they have been used to[36]. The dimensions of the ILS where participants have higher CCI scores (reflexive, intuitive) correlate to the teaching styles of many engineering courses where theories are taught in a lecture format and students are expected to process the information individually[17].

The initial data only allows us to make any claims about the mild degree of preference across the learning styles dichotomies. Though they did not have the highest CCI average, mild learners in the active/reflexive, sensing/intuitive, and sequential/global dichotomies did show increases in CCI averages across classifications, suggesting that having a mild preference does lead to gains in intellectual development. This may be due to students with a milder preference having the ability to adapt their learning style depending on the teaching methods with more ease. Though these results are promising, we acknowledge the need to increase the sample sizes.

In the future, we will continue to collect additional data and analyze to see if the observations seen so far hold for larger populations across classifications. We will include GPA in future background survey to serve as another baseline for the research that most people use as a measure of intellectual development. We will also look at other factors like internships and military experience and see if they have any type of impact as well.

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