*36-303: Sampling, Surveys and Society*

**Spring 2010**

# Evaluation of innovation attributes in order to meet the challenges of global knowledge economy

*Final Report*

**Nice job.**

**Glad you were in the class. I hope it was useful to you.**

**As I think I've said before, if you have any ideas about how to "tune" this material for grad students in the future, please feel free to let me know.**

**all best,**

**-BJ**


*BARADARAN SHORAKA, MOHAMMAD*

*GALVAN, JOSE ALFREDO*

*LEONTIADIS, NEKTARIOS*

*YANG, CHIA-HSUAN*

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# 2. Introduction

## 2.1. Research questions and motivation

Innovation is a subject of much relevance. Since the 30's, Joseph Schumpeter developed studies on how capitalism is affected by market innovations. He established that innovation is a creative destruction (1). At the end of the 20th century, the world experienced more intensely the effects of innovation. The creation of new products, processes, and procedure was constant. Each one of us could feel the effects of innovation, as companies continually create new products to compete in the global marketplace. For example the cellular phone industry is constantly creating new products; launching a new model before we learn to use that we bought.

Just as happened in the last decade of the 20th century, in the 21st century, nations, states, businesses, and individuals must meet the challenges of the global knowledge economy to create value. The ability to innovate in each of these levels depends on the capacity for innovation (2). Since 2002, Canada has been implementing a national strategy of innovation. In which established, the innovation as an engine for the development of the country. The Prime Minister Jean Chrétien said "prosperity depends on innovation, which, in turn, depends on the investment that we make in the creativity and talents of our people"(3) (4) (15).

It is becoming increasingly relevant and important features of human capital that is developed at universities. The recruitment processes are focused on recruiting the best candidates for each vacancy. The companies need not only the technical competence. They seek those who demonstrate broader skills such as: ethical and professional responsibility, social awareness and sustainability, teamwork, communication, information, gathering, problem definition, idea generation, evaluation and decision making, implementation capacity, teamwork, and the capacity to for life-long learning (5) (6) (7) (8) (9) (10).

Rao et al (2002) conducted a study concluding that "experienced employees and new university graduates, cooperation with other firms, product market competition, and government support for R & D, training, and technical assistance are the drivers of innovation" (11). For instance, the 3M Company is looking for "invetorpreneurs". Inventorpreneur is a person that" invents or creates a new product that fulfills a defined need, promotes the new opportunity or product, manages, organizes and assumes many risks in Establishing a new business based on that product " (12).

It is important to recognize that the ability to innovate are not learned in one course, this means the ability to innovate pair is the result of various skills acquired through academic life. The integration of attitudes, skills and knowledge is known as competition (13) (14). The sum of competences known is known as a metacompetence. Radcliffe states that the innovative competence is a metaat tribute. "It is not a merely another set of knowledge or skills to be taught in addition to the regular curriculum" (9).

The research questions that we intend to answer with this survey are:

1. Which are the most important characteristics to develop innovation skills in the university students, and
2. Which are the most powerful educational elements that promote the innovation skills?

## 2.2. Quick summary

| | |
|---|---|
| Purpose | Evaluate the characteristics that are related to the skills and attitudes that the graduate students need, in order to be more innovative in their future jobs. |
| Duration | 03/21/2010 – 03/26/2010 |
| Target population | Master and PhD students of CMU whose area of research or curriculum is relative to engineering, industrial design or business administration |
| Sampling frame | Students in the target population that either have past job experience or they have been in CMU long enough to be able to have an opinion. The latter is identified either by the student graduating in the current year or by having taken the qualification exams. |
| Sample design | SRS on people with specific characteristics that fit to the target population based on the CMU directory. They respondents also were self-placed in the sampling frame based on their responses in the survey. |
| Sample size | 77 |
| Use of interviewer | None |
| Mode of administration | Web-based, self-administered |
| Computer assistance | Web entry |
| Reporting unit | Randomly selected CMU graduate student |
| Time dimension | Cross-section design |
| Frequency | One time execution |
| Interviews per round of survey | One |
| Levels of observation | Graduate student, previously employed student, student being long time in college |
| Web link | http://cli.gs/prrHM |

**Table 1 Survey: Evaluation of innovation attributes in order to meet the challenges of global knowledge economy**

# 3. Methods

## 3.1. Survey setup

Based on the Carnegie Mellon University 2009-2010 Factbook[1] there are 3715 graduate students enrolled in Engineering, Business, and industrial Design departments.

We are using the 5 points scale for the answers. The worst case will be when the respondents answer 5 scales in an equal amount which will cause the probability of each scale to be 20%. Therefore, the standard deviation will be 0.4, as shown below.

$$SD = \sqrt{p(1-p)} = \sqrt{(0.2) \times (1-0.2)} = 0.4$$

The confidence interval we chose for our survey is 95% and the margin of error is ±0.10. The reason why we chose the ±0.10 margin of error is that this is a scientific experiment and there are a lot of unknown facts and assumptions that could affect the results.

Our sampling method is SRS without replacement, so we will need n=61 respondents so that we could fulfill this confidence interval and margin of error which is calculated as:

$N = 3715\ persons$

$SD = 0.4$

$ME = 0.1$

$$n_0 = \frac{z_\alpha^2 \times SD^2}{ME^2} = \frac{1.96^2 \times 0.4^2}{0.1^2} = 61.47$$

$$n = \frac{N \times n_0}{N + n_0} = \frac{3715 \times 61.47}{3715 + 61.47} = 60.46 \rightarrow n = 61$$

We know that if we would like to improve the margin of error to ±0.07 with the same confidence interval and standard deviation, we will need near twice the amount we need now, which will be 121 respondents. And for a margin of error of ±0.05 we will need 231 respondents.

With assuming a 20% response rate, we will need to contact 305 respondents to fulfill the confidence interval and margin of error. The actual number of respondents we used in our survey is 320 persons.

Instead of using the C-BOOK to generate our random sample we decided to utilize CMU's online student, faculty and stuff directory. This directory is based on the Lightweight Directory Access Protocol (LDAP) and holds an extensive amount of information for each person that is affiliated with CMU, like type of affiliation (e.g. student), level of a student (e.g. graduate), college that a student is affiliated with (e.g. Carnegie Institute of Technology), etc.

[1] http://www.cmu.edu/ira/factbook/pdf/facts2010/2_fact-book_webversion_2009_10_enrollment1.pdf

The important characteristic of LDAP that made us elect it as a method of sample generation is that it enables queries to be executed on the characteristics of the directory items. Moreover one can select which types of information she wants to receive as a response to a query (e.g. first name, last name, email address, etc.). As a consequence, by properly using this tool, we are able to generate a targeted sample, as defined by the target population.

The following is a sample query that retrieves graduate students, who are doing their masters at the Tepper school of business.

```
(& (eduPersonAffiliation=Student) (! (eduPersonAffiliation=Stuff))
(|(cmuStudentLevel=Graduate) (cmuStudentClass=Masters))
(eduPersonSchoolCollegeName=David A. Tepper School of Business) )
```

We should note that there exists a limitation in the results that can be retrieved through LDAP; the maximum amount of results (i.e. contact details) that one can get from a single query is 200. That means that for a specific query, we always get the same first 200 results. This limitation is introduced by the administrators of the directory to prevent certain types of web based attacks. This limitation could potentially prevent us from using this approach to generate the sample, as bias would be introduced by excluding people from the sample.

First, in order to overcome the problem of excluding people from certain groups, we followed the following procedure: instead of running one query that covers the whole target population but that would give only 200 contacts, we divided it to a number of consistent sub-queries. That means that we run a separate query for each college that we are interested in and for each college we run one query for the master students and another one for the doctoral students. This process resulted in a few groups of contacts, each one of which had the same characteristics. In the next step we combined all these groups into one list and we shuffled it programmatically a few times to make sure that a sequential selection of contacts from this list would lead to a **random sample**.

Second, the possibility of having bias within a specific group, by selecting the first 200 of each group and excluding the rest is resolved by the nature of LDAP; each item in the directory is identified by a universally unique and completely random identifier that is neither dependent on any attribute of the contact that is associated with nor on chronological order of entry in the directory. The LDAP uses this identifier to sort the results of a query and to retrieve a given contact. Given these characteristics of the identifiers we assume that the bias introduced by having access to a limited number of results per query is **completely at random** and it doesn't interfere to the quality of the survey results.

Through this process we were able to generate a random sample of 640 people. This sample was divided into two groups (pools) of 320 people. Each person in the initial sample had equal probability of being included in any of the two resulting pools. The number of people in each

pool was chosen to accommodate the 60 responses that we require in order to achieve a confidence interval of 95%, having in mind that the response rate to a web-based survey is around 15% to 20%. Also, as we have defined in our sampling plan, we generated two pools of samples so that if we failed to get the required amount of responses (after contacting the first pool of sample), we would contact the people in the second pool.

## 3.2. Data collection

The tool that we used for the data collection process is survey monkey (www.surveymonkey.com). After creating the survey using the tools provided by the website, we initiated the collection process (on Monday 3/21/2010, 12:10am) by sending email invitations to the first sample pool. This process was carried out by the website and it required a list of names and email addresses. Within the first 4 days of the survey we managed to get around 40 responses. The response rate had stalled by the end of the 4$^{th}$ day and we proceeded by sending a reminder to the people that had not responded and had not opted-out from participating after receiving the first invitation. The reminder e-mail was sent out on Thursday, 3/25/2010 at 12:15am. The survey was ended on Friday, 3/26/2010 at around 5pm after having received 77 responses (57 complete and 22 partial) and 17 denials to participate.

An initial page containing the consent form (see table 11), was designed to be presented to each survey participant that made sure that the participant met some basic requirements and would have basic understanding about the survey process. If the respondent did not qualify to answer the survey, he/she would be redirected to the end of the survey without participating in it.

## 3.3. Post-survey processing

### Reviewing the collected data

An initial review of the collected data showed that there were a few responses needed to be excluded from further processing and inclusion in the survey results because of a number of reasons, namely:

- Lack of full agreement to and acknowledgment of the content of the consent form (3),
- Non-compliance with the definition of the target population for this survey (1), and
- Item non-responses in the main part of the survey (i.e. completed only the demographic part of the survey) (5).

Regarding the latter, we observed that these 5 responses did not have any specific characteristics that made them special – in any way – related to the rest the responses, so the error introduces by not including them – if any – would be completely at random.

After this initial cleaning process, we end up having 68 valid responses.

Further review of the collected data showed that some people responding to question 14 (“In which academic level are you studying at CMU?”) indicating that they are doing a master they also responded to the optional question 15 (“If it is PhD, have you taken the qualification

exams?") indicating that they haven't taken the qualification exams. In these cases we assumed that some respondents pursuing a PhD degree who haven't passed the qualification exams would identify themselves as master students instead of PhD students. Thus, we decided to correct these responses and set the value of question 14 to PhD if the responder has responded to question 15.

### Imputation

The responses included a number of item non-responses. We decided to perform a hot-deck imputation to fill in the missing data. In order to do that, we used as a first level of ordering the **"current major"** data and as a second level of ordering the **"nationality"** data. Following this re-ordering process we filled in the missing information based on this imputation method. We were able to fill missing entries for all but one response. In this one case where there was no matching record - as defined by the hot-deck imputation method – we used a number of characteristics to find the best match.

### Post-Stratification

Because of the fact that the method of sample selection was based on simple random sampling and there was also a self-selection process involved, we decided to perform post-survey stratification based on three well-defined strata. By "well-defined" strata we mean groups of people the numbers of which can be verified by the CMU Factbook. Based on the information in the Factbook and the survey-based collected data, we defined three (3) strata that would be used for post-survey processing; gender, current CMU school or college and academic level. Actual and survey-based numbers for each of these strata are summarized in Table 5, Table 7 and Table 8 .

Looking into the 12 combined strata that are the result of the combination of the 3 individual strata, we identified that the stratum for female engineering students, doing their masters at CMU, was empty. So, we decided to eliminate the gender strata and we ended up with two individual strata or 6 combined ones.

**Table 2 Weights for college strata**

| Academic Program | No. of respondents | Percentage of the respondents | Population | Percentage of the population | Weights |
|---|---|---|---|---|---|
| **Industrial Design** | 4 | 6% | 43 | 1% | 0.20 |
| **Engineering** | 20 | 29% | 1468 | 40% | 1.34 |
| **Business** | 44 | 65% | 2204 | 59% | 0.92 |
| **Total** | 68 | 100% | 3715 | 100% | - |

Table 3 Weights for academic level strata

| Academic Level | No. of respondents | Percentage of the respondents | Population | Percentage of the population | Weights |
|---|---|---|---|---|---|
| **Masters** | 40 | 59% | 2870 | 77% | 1.31 |
| **PhD** | 28 | 41% | 845 | 23% | 0.55 |
| **Total** | 68 | 100% | 3715 | 100% | - |

Thus, if D denotes Industrial design, E engineering, B business, M masters and D doctoral students, the following table summarizes the post-survey stratification weights that we are using.

Table 4 combined strata weights

| DM | DP | EM | EP | BM | BP |
|---|---|---|---|---|---|
| 0.258 | 0.109 | 1.764 | 0.742 | 1.204 | 0.506 |

Each of these weights was applied to one or more of the collected responses, depending on the stratum that each specific response belongs to. As a result we end up with a balanced data set.

## 4. Results

We had 77 persons contributing in our survey which 9 of them failed to fulfill the requirements which means we had 68 participants.

$N = 3715\ persons$

$SD = 0.4$

$n = 68\ persons$

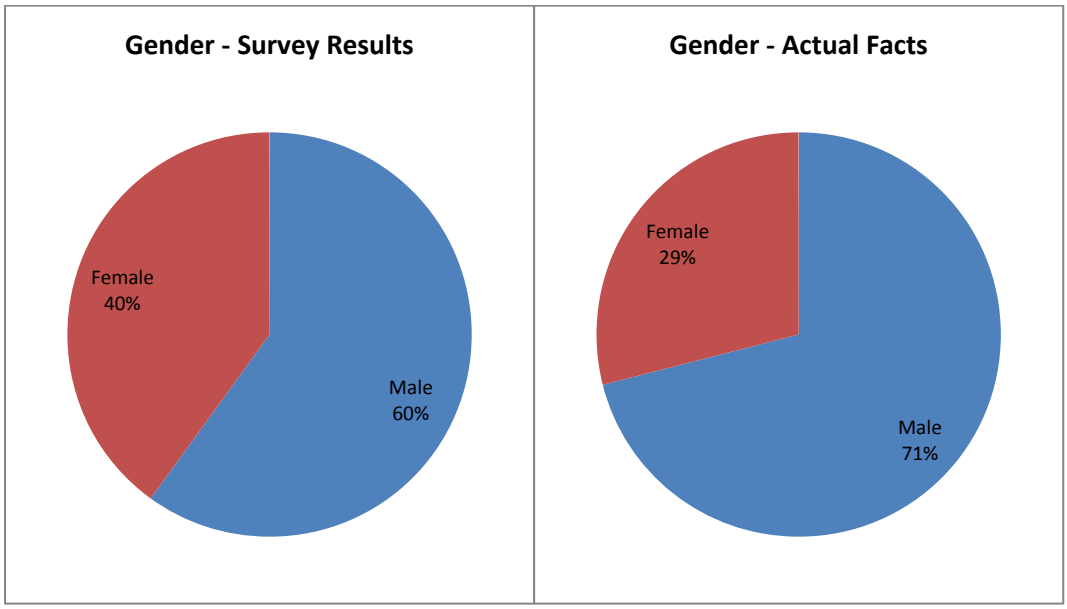
$$ME = \frac{z_\alpha \times SD}{\sqrt{n}} = \frac{1.96 \times 0.4}{\sqrt{68}} = \pm 0.095$$

$$Response\ Rate = \frac{68}{320} = 21\%$$

So our real margin of error is ±0.095 and our response rate is 21%.

Looking at the answers of the 68 respondents for the demographic questions, we have this information:

1. 60% are male and 40% are female (refer to Table 5);

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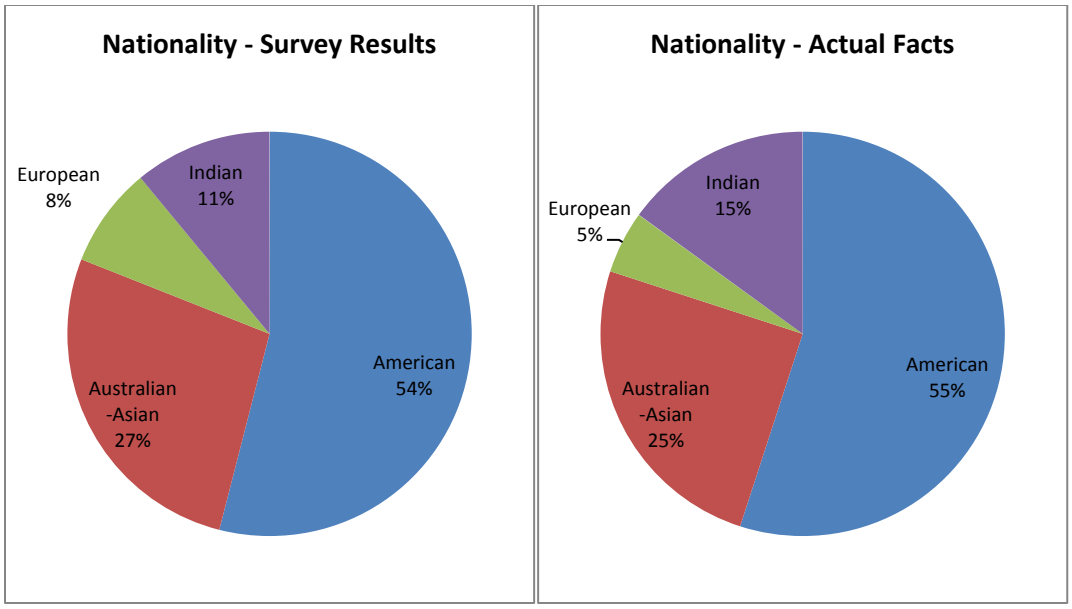
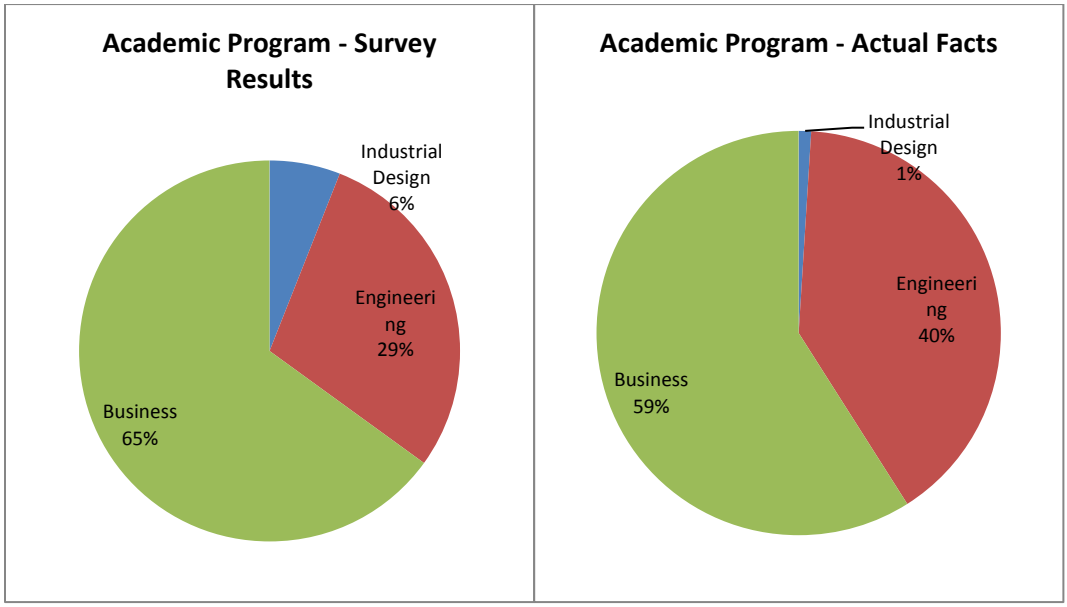
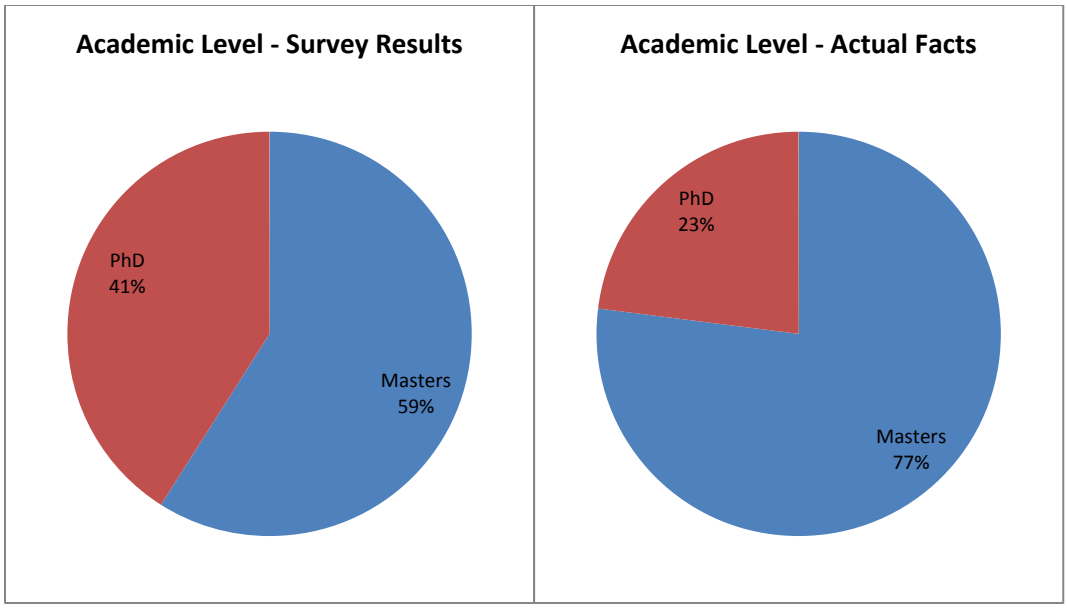
2. The nationalities are divided into four regions, 54% American, 27% Australian-Asian, 8% European and 11% Indian (refer to Table 6);




3. 27% have an age of 20-25, 36% have an age of 25-30, 12% have an age of 30-35, 10% have an age of 35-40, and 15% have an age of 41 and more;
4. 6% are in the Industrial Design program, 29% are in Engineering and 65% are in the Business program (refer to Table 7);




5. 8% have an previous degree in Design, 43% were in Engineering, 33% were in Business and 24% were in other programs;
6. Out of the 69% that have work experience, 47% have 1-5 years of work experience, 30% have 5-10 years, 13% have 11-15 years, and 10% have 16 years or more of work experience;
7. Out of the 71% that have attended an internship, 15% have done 1-2 month, 60% have done 3-4 months, 10% have done 5-6 months, and 15% have done 7 months or more;
8. 59% are Master students and 41% are PhD students (refer to table 8);




9. Out of the 41% that are PhD students, 79% have taken their qualification exam;
10. 51% are graduating within this year.

**Table 5 Gender information**

| Gender | No. of respondents | Percentage of the respondents | Total No. of students | Percentage of the total No. of students |
|---|---|---|---|---|
| Male | 41 | 60% | 2624 | 71% |
| Female | 27 | 40% | 1091 | 29% |
| Total | 68 | - | 3715 | - |

**Table 6 Nationality information**

| Nationality | No. of respondents | Percentage of the respondents | Total No. of students | Percentage of the total No. of students |
|---|---|---|---|---|
| American | 34 | 54% | 2888 | 55% |
| Australian-Asian | 17 | 27% | 1298 | 25% |
| European | 5 | 8% | 762 | 5% |
| Indian | 7 | 11% | 245 | 15% |
| Total | 68 | - | 5193[2] | - |

[2] The information in this category includes all the students studying Masters and PhD in any academic program.

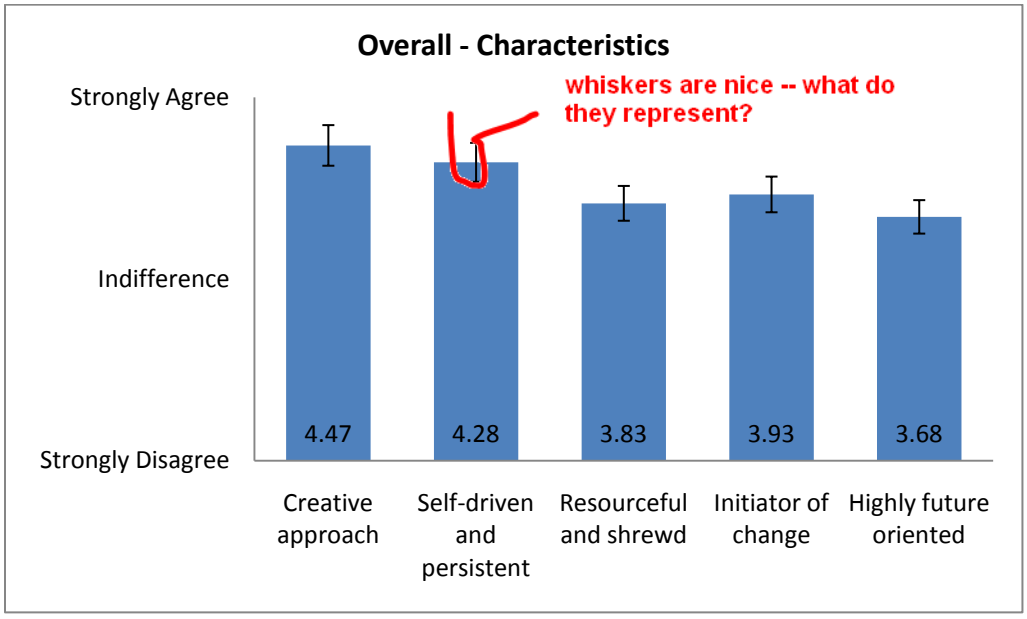
Table 7 Academic program information

| Academic Program | No. of respondents | Percentage of the respondents | Total No. of students | Percentage of the total No. of students |
|---|---|---|---|---|
| Industrial Design | 4 | 6% | 43 | 1% |
| Engineering | 20 | 29% | 1468 | 40% |
| Business | 44 | 65% | 2204 | 59% |
| Total | 68 | - | 3715 | - |

Table 8 Academic level information

| Academic Level | No. of respondents | Percentage of the respondents | Total No. of students | Percentage of the total No. of students |
|---|---|---|---|---|
| Masters | 40 | 59% | 2870 | 77% |
| PhD | 28 | 41% | 845 | 23% |
| Total | 68 | - | 3715 | - |

What is obvious is that the respondents have a stronger agreement that characteristics (including with the order of more agreement of Creative approach, Self-driven and persistent, Initiator of change, Resourceful and shrewd, and Highly future oriented) and attributes (including with the order of more agreement of Curiosity, Persistence, Commitment, Challenge Seeking, and Aggressively ambitious) are important in being innovative and are indifferent about values (including with the order of more agreement of Integrity, Respectful to others, Personal and social responsibility, Freedom, and Peace).

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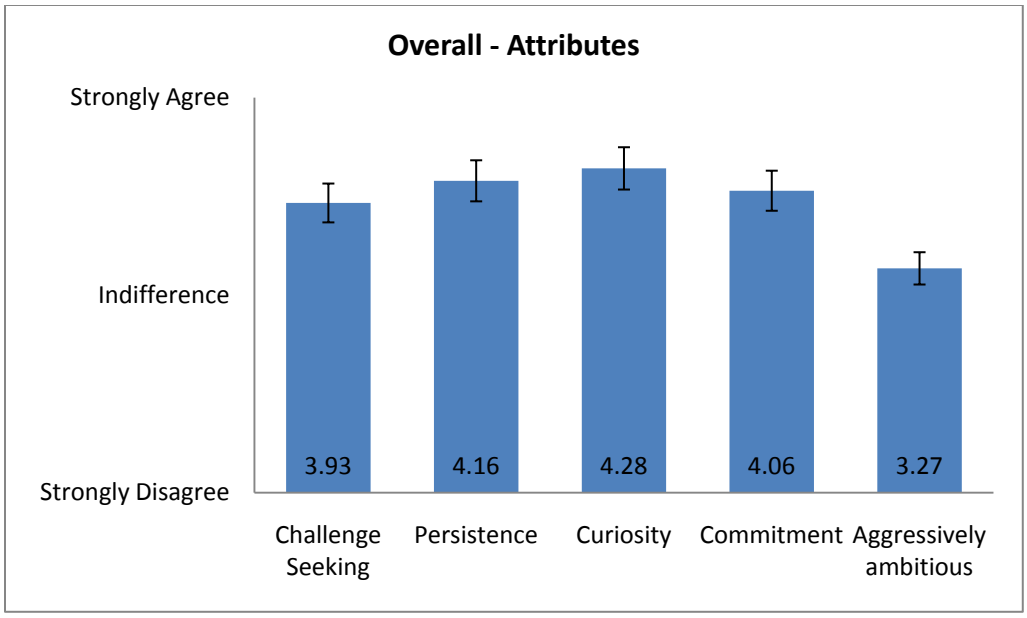
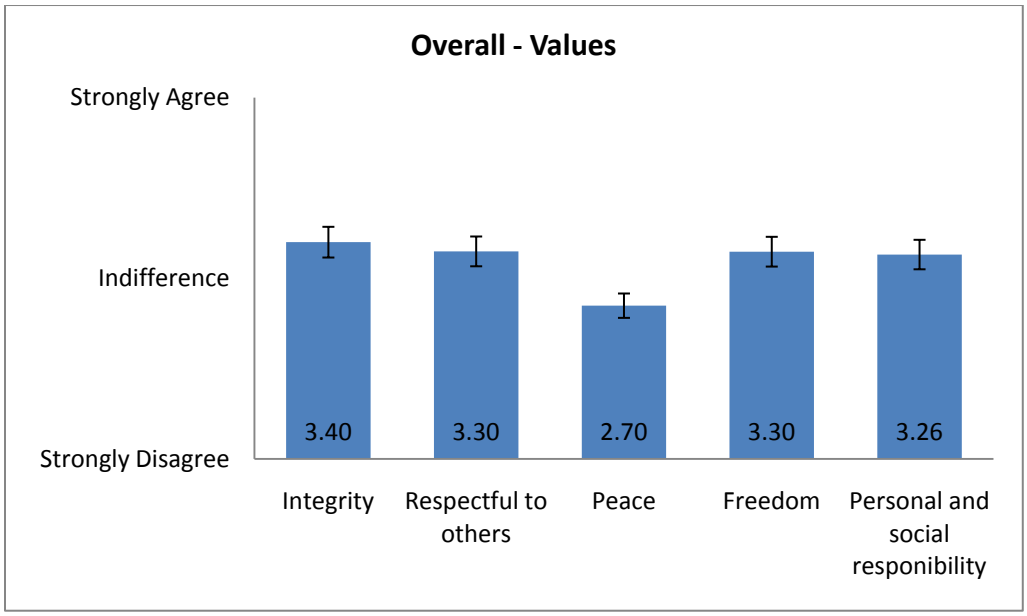



The respondents think Technical knowledge (Technology, methods, engineering, production, etc) is the most important knowledge someone would need to be innovative followed by Design, Business, and Law and legal knowledge. Some thought other facts are important like resources, pushing the boundaries, cultural knowledge and awareness, people/collaborative skills, creativity, and having good ideas.

| | Knowledge | | | |
|---|---|---|---|---|
| | Business | Technical | Design | Law or legal |
| Overall | 3 | 1 | 2 | 4 |

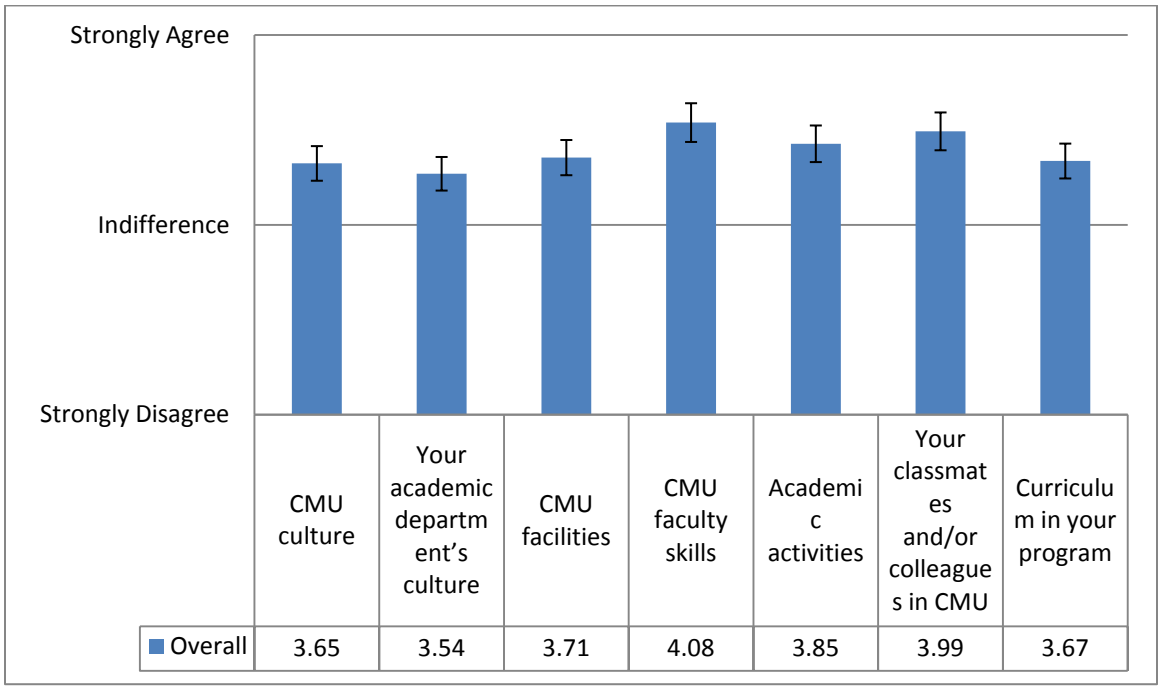
The respondents agree that both contribution of CMU culture and the impact of the academic department's culture are important to promote a person's innovation ability. Some effective parts of the academic department's culture are Supportive people, Interdisciplinary, academic expertise of faculty members, competence of students, passion, Teachers teaching abstract concepts, Space to work in groups, Coursework, Diversity, and Students organizations. On the other hand they think some parts are not effective like not enough open communication in department, Lack of fund, Open-ended problem solving, Not enough free thinking assignments where students are to challenge their creative side to make a solution, Too many restrictions on collaboration in some classes (class policy), Resources, The balance of political viewpoints, Cross collaboration, interaction with other students, No incentive to be innovative, and Inconsistency in the quality of instruction. Some solutions to improve this non-effective parts of the academic department's culture are: Invest more money for the office, studio environment, Include open-ended problem solving to classes where possible, Offer assignments to solve global problems and evaluate based on creativity and feasibility, and Balance with more conservative political viewpoints.

This group thinks that the influence of CMU facilities, like libraries, laboratories, classrooms, gyms and business incubators are important for improving students' innovation ability. Same as before, the effective parts are: Updated laboratories and offices, Space and resources to think, research and collaborate, A lot of professors are innovative minds, Good spaces for interacting with other students, and the non-effective parts are: Lack of public spaces, Not enough coerced activities to bring about relationship building activities, Clusters, Limited access to resources, and The cultural activities and cross-related partnerships. The respondents did not know useful way to improve the non-effective parts.

The respondents agree that CMU faculty skills and the effect of academic activities (like seminars, meetings, etc.) in CMU are important for improving students' innovation ability. Effective parts helping the importance of these skills are: They hear about new research areas, Lots of seminars, lectures from outside experts, Exposure to new ideas and constructive criticism, CMU brings in prominent keynote speakers for seminars regularly, and The cross disciplinarily knowledge. The non-effective parts are: They are time consuming, Criticism, Conflict in schedule, Lack of student discourse, Hard to figure out which activities will be useful, and Sometimes it is too technical and it is hard to understand. Some ways of improving the non-effective parts are Create time, Hire the best teachers, Make some mandatory or extra credit for class to encourage attendance, Encourage participation, Schedule activities for non-working hours during the week, and Improve the lectures.

The respondents also think that the impact of classmates and/or colleagues in CMU and the curriculum in the academic program and the influence of CMU facilities and the effect of academic activities are important for improving students' innovation ability. Some effective parts of the facilities and activities are: Structured curriculums, well-grounded content, help students think systematically, holistically, Students push one another and openly discuss technical issues and often discuss potential solutions to the problems, Classes and friend, Group

assignments, Instructors who are demanding and structured in their approach, and Using case studies and real life examples. The non-effective parts are: Everyone is so busy with their own research, Lack of attention to individual students, Innovations with impacts are generally limited to thesis research, Collaboration policies can be restrictive, Lack of engaging research opportunities, Empirical courses were too far away from reality, Some instructors more committed than others, Some ways of improving these parts are: Open discussion of course material, Introduce systems to gauge performance effectively and also deal with student psychological issues, Focus on project work, More offerings to work with faculty on faculty research projects, and By creating a closer relationship between empirics and everyday business life.




| | CMU culture | Your academic department's culture | CMU facilities | CMU faculty skills | Academic activities | Your classmates and/or colleagues in CMU | Curriculum in your program |
|---|---|---|---|---|---|---|---|
| Overall | 3.65 | 3.54 | 3.71 | 4.08 | 3.85 | 3.99 | 3.67 |

We continue the discussion by analyzing the data for each category.

## 4.1. Academic Level

This category is divided into two groups, Masters and PhD students.

Master and PhD students had the same opinion in most criteria. They totally agree that "Characteristics" are important to be innovative and they agree that Creative Approach is the most important in this criterion. These students also agree that "Attributes" are important to be innovative too but not as important as characteristics. They agree about all attributes except Aggressively Ambitious which they were indifferent about it. It was totally different with "Values". Both groups thought that all values studied in the survey are indifferent in being innovative.

Master students think Design Knowledge (conceptualization, creativity, form, ergonomic issues, etc) is the most important knowledge needed to be innovative followed by Technical, Business,

and law and legal knowledge. PhD student on the other hand thought Technical knowledge (Technology, methods, engineering, production, etc) is the most important knowledge someone would need to be innovative followed by Design, Business, and Law and legal knowledge.

Master students are indifferent about the contribution of CMU culture significance and the impact of the academic department's culture to promote a person's innovation ability. This group thinks that the influence of CMU facilities, like libraries, laboratories, classrooms, gyms and business incubators and the effect of academic activities (like seminars, meetings, etc.) in CMU, are indifferent too for improving students' innovation ability. They also think that the impact of classmates and/or colleagues in CMU and the curriculum in the academic program are indifferent in fostering a student's innovation ability.

PhD students which contradict with the Master students, agree that both contribution of CMU culture and the impact of the academic department's culture are important to promote a person's innovation ability. They also think the influence of CMU facilities and the effect of academic activities are important for improving students' innovation ability. This group thinks that the impact of classmates and/or colleagues in CMU and the curriculum in the academic program have a significant effect in fostering a student's innovation ability.

Overall, as you can see both groups agree that Characteristics and Attributes are important and they are indifferent about the Values. They totally contradict about the other matters. The Master students are indifferent about all of them but PhD students agree that they are important in improving their innovation abilities.

An extended graphical analysis of the findings can be found in Appendix A.

### 4.2. Nationality

The nationalities are divided into four regions, America, Australia-Asia, Europe and India.

Graduate students from those four regions, had the same opinion in most criteria. They totally agree that "Characteristics" are important to be innovative. They strongly agree that creative approach is the most important in this criterion. They strongly agree that "Attributes" such as curiosity is important to be innovative. They are indifferent with aggressively ambitious. Graduate students for the four regions thought that all values studied in the survey are indifferent to be innovative.

Graduate students from America think Design knowledge (conceptualization, creativity, form, ergonomic issues, etc.) is the most important knowledge needed to be innovative followed by Technical, Business, and law and Legal knowledge. Graduate students from Australia-Asia and India think that Technical knowledge (technology, methods, engineering, production, etc.) is the most important knowledge someone would need to be innovative followed by Business, Design, and Law and Legal knowledge. Graduate students from Europe on the other hand thought Business knowledge (business plan, marketing, market needs, etc.) is the most important

knowledge someone would need to be innovative followed by Technical, Design, and Law and legal knowledge.

Graduate students from those four regions are indifferent about the contribution of CMU culture and the impact of the academic department's culture in the promotion of innovation ability. Those graduate students think that the influence of CMU facilities (like libraries, laboratories, classrooms, gyms and business incubators) is indifferent too for improving students' innovation ability. They also agree that the impact of CMU faculty skills, academic activities (like seminars, meetings, etc.) and classmates-colleagues are important in fostering student's innovation abilities. Except for Graduate students from Europe, they strongly agree about CMU facilities and classmates-colleagues are important in improving innovation abilities. Graduate students from India are indifferent about the curriculum program; they think that it has not a significant effect in the development student's innovation abilities.

Overall, as you can see four regions agree that "Characteristics", "Attributes", faculty skills, academic activities and classmates-colleagues are important and they are indifferent about the "Values", CMU culture and the impact of the academic department's culture.

An extended graphical analysis of the findings can be found in Appendix B.

### 4.3. CMU Graduate Programs (Schools)

The CMU Graduate Programs is divided into four groups, business, design-arts, engineering, and public policy programs.

Graduate students from the four groups of programs had the same opinion in most criteria. They totally agree that "Characteristics" are important to be innovative and they strongly agree that creative approach and self-driven and persistent are the most important in this criterion. Business Graduate students are indifferent that highly future oriented is needed to be innovative. They strongly agree that "Attributes" such as curiosity is important to be innovative. They are indifferent with aggressively ambitious. They were totally indifferent with "Values" except graduate students from Design-Arts that they agree with peace and freedom and strongly agree with integrity, respectful for others and personal and social responsibilities are important to be innovative.

Regards "Types of knowledge" each academic program claimed that the most important knowledge is related with their program. Graduate students from business programs think Business knowledge (business plan, marketing, market needs, etc.) is the most important knowledge needed to be innovative, followed by Technical, Design, and Law and Legal knowledge. Graduate students from engineering programs think that Technical knowledge (Technology, methods, engineering, production, etc.) is the most important knowledge someone would need to be innovative followed by Design, Business, and Law and Legal knowledge. Graduate students from Design-Arts programs think that Design knowledge (conceptualization, creativity, form, ergonomic issues, etc.) is the most important knowledge needed to be innovative, followed by Technical, Business, and Law and Legal knowledge. In

overall graduate students recognize in first position Technical, Design, Business and finally Law knowledge in order to be innovative.

Graduate students from the Business, Engineering programs agree and Design-Arts graduate students strongly agree about the contribution of CMU culture, impact of the academic department's culture, influence of CMU facilities (like libraries, laboratories, classrooms, gyms and business incubators), effect of academic activities (like seminars, meetings, etc.), impact the curriculum program, CMU faculty skills and classmates-colleagues are important to be innovative.

Overall, Graduate students strongly agree that "Characteristics" such as creative approach and self-driven and persistent. They strongly agree that "Attributes" such as persistent and curiosity, but they are indifferent with aggressively ambitious is important to be innovative. In contrast, they are indifferent about the "Values" except Design-Arts graduate students.

An extended graphical analysis of the findings can be found in Appendix C.

### 4.4. Gender

Based on the gender property of respondents, the survey results are divided as two groups: female and male.

Female and male students had the same opinion in most criteria. They both agree that "characteristics" are important to be innovative and "creative approach" is the most important characteristics followed by "self-driven and persistent". They also agree that "attributes" on the list are important to be innovative but not as important as characteristics. Female students believe "curiosity" is the most important attribute and "commitment" is the second; male students believe "curiosity" and "persistence" are the two most important attributes. They both believe that "aggressive ambitious" are slightly related to be innovative. Compared with the above two criteria, both female and male students show that "value" is not as important as "characteristics" and "attributes" be. Among the values on the list, female students believe that the most important value is "personal and social responsibility" and the second important values are "respectful to others" and "integrity"; male students believe "integrity" is most important and "freedom" is second important. Overall female students evaluate higher on this criteria.

Female and male students show slightly different opinion on which knowledge is important to be innovative. Female students believe design knowledge is most important followed by technical, business, and law or legal knowledge. Male students believe technical knowledge is most important followed by business, design and law of legal knowledge.

Both genders evaluate that overall CMU environment contributes to promote students' innovation ability positively. Both female and male students weakly agree that culture of CMU, culture of their own department, program curriculum, facility and academic activities in CMU influence student to be innovative. Female students evaluate the facility and CMU culture

slightly higher than male students do; male students evaluate department culture higher than female students do. They both believe that the faculty skills and classmate/colleagues in CMU have significant impact on promoting students' innovation ability.

Overall, as we can see both genders agree the importance of "characteristics" and "attributes" on being innovative and are both indifferent about "value". They have different opinion on the importance of knowledge. Female students rank design knowledge as the most important one; male student rank technical knowledge highest instead. Both genders show indifferent or weak agreement about the significance of the influence of most CMU elements on students' innovation ability, but they both agree that faculty skills and classmate/colleagues in CMU have significant impacts.

An extended graphical analysis of the findings can be found in Appendix D.

### 4.5. Work or Internship Experience

Based on the work experience property of respondents, the survey results are viewed by four classifications: without work or internship experience (few samples), with only work experience, with only internship experience, and with both kinds of experience.

Every group of respondents had the same opinion in most criteria. All of the groups agree that "characteristics" is important to be innovative. In the characteristics on the list, most of them agree that "creative approach" is the most important characteristics, except the group without work or internship experience, in which believe "self-driven and persistent" is most important. The group with both work and internship experience evaluate the impact of "characteristics" on being innovative higher than other groups. All of the groups also agree that "attributes" is important to be innovative. Students without work or internship experience believe "curiosity", "persistence" and "aggressively ambitious" are the most important attribute; students with only work experience believe "commitment" is the most important attribute followed by "curiosity"; students with only internship experience believe "persistence" and "commitment" are the two most important attributes followed by "curiosity"; students who have both work and internship experience believe "curiosity" is the most important attributes followed by "persistence". All of the latter three groups believe "aggressively ambitious" is the less important one. Compared with the above two criteria, all students show that "value" is not as important as "characteristics" and "attributes". Especially, students without work and internship experience disagree that "value" is important to be innovative based on overall evaluation of five values on the list. Other students slightly agree the importance of value on being innovative. Among the values on the list, student with only work experience response "respect to others" is most important and "integrity" is second important; students with only internship present "integrity" is most important and "personal and social responsibility" is second important; students with both work and internship experience believe "freedom" is the most important value and the second important values is "integrity". All the four groups think "peace" is not important value for being innovative.

All classifications show same opinion on which knowledge is important to be innovative. The group of student with only work experience represent that “design” is the most important knowledge followed by “business” and “technical”, which are equally important. All other groups believe technical knowledge is most important followed by design, business, and law or legal knowledge.

Most of the four groups evaluate that overall CMU environment contributes to promote students’ innovation ability positively. Students without work and internship experience believe CMU culture and their department culture are indifferent to promote a student’s innovation ability. They agree that CMU facility and faculty skills have significant impact on students’ innovation ability and slightly agree the impact of academic activities, classmate or colleagues and the program curriculum. Student with only work experience weakly agree that the CMU environment influences students’ innovation ability significantly. This group of students score faculty skills highest compared to other elements. All other groups agree that the faculty skills and classmate/colleagues in CMU have significant influence on students to be innovative. Students with both work and internship experience also agree that academic activity has impact on students’ innovation ability but weakly agree the impact of other elements. Student with only internship weakly agree the impact of other parts (i.e. academic activities, CMU facility, department culture, program curriculum, CMU culture) on the innovative ability of CMU students. Students who have both work and internship experience evaluate the influence of CMU on students’ innovation ability higher than other groups.

Overall, as we can see all groups agree “characteristic” and “attributes” are important and are not significantly agree the importance of “value”; the group with no work or internship experience even disagree the importance of value on being innovative. All groups rank technical knowledge as the most important one, except the group with only work experience rank design knowledge highest instead. All groups agree the impact of faculty skills and classmates/colleagues in CMU are significant except the group with only work experience, who weakly agree the two elements.

An extended graphical analysis of the findings can be found in Appendix E.

## 5. Discussion

Taking into account the methodology and all our findings discussed extensively in the previous chapters, we can definitely conclude that at the end of this study, we were able to successfully execute a survey and draw scientifically significant inferences as answers to our research questions; the parameters that promote innovative thinking and the action(s) that CMU can take towards this end.

The parameters that we though significant enough to investigate were the **characteristics**, the **attributes**, the **values** and the **kinds of knowledge** that a graduating student needs to be characterized with or possess in order to be highly innovative. Our findings show that it is of significant importance that such a person should show a creative and should be self-driven and persistent. That person should have curiosity embedded in its mentality and a strong technical background. While the latter is accepted by students of all majors, each group (e.g. business, design, etc.) had a tendency to give a relatively higher importance to their own field of study.

An observation that needs to be pointed out is that most of the respondents were indifferent regarding the importance of the values that were presented with for being innovative. This can either be interpreted as failure on our behalf to evaluate the correct values or that this kind of parameters really does not play any significant role. In the same track, design school students have a slight tendency to consider all the values relatively important.

Another group of students that makes a difference because of its choices are the European students. Throughout the results they always show stronger opinions (i.e. they prefer the stronger versions of the answers) and they slightly differentiate themselves from the majority; except from the general observations stated above, European students believe that the ideal graduate should also be challenge seeking, aggressively ambitious, highly future oriented and change initiator. These characteristics probably reflect a different mentality between the other ethnic groups of students and the European one.

Finally, regarding the role of the University in building the ideal innovation graduate, it is a unanimous belief that the faculty members play the most significant role to that end.

Overall, we can conclude that we now have a more clear view of the aspects that can built a more innovative economy by better preparing the innovation units (i.e. the people) to play that role.

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# 7. Appendices

## 7.1. Part I

**Table 9 Invitation to participate to the survey**

| |
|---|
| Dear FIRSTNAME LASTNAME,<br>We are a group of 4 CMU students that is currently running an on-line survey which intends to identify the importance of different aspects of college life (e.g. facilities, faculty interaction) for the improvement of the innovation abilities of the students. We would like to invite you to complete the survey. We only request less than 5 minutes of your time.<br><br>Here is a link to the survey:<br>http://www.surveymonkey.com/s.aspx<br><br>This link is uniquely tied to this survey and your email address. Please do not forward this message.<br><br>Thank you in advance,<br>Jose Alfredo Galvan - jagalvan@andrew.cmu.edu<br>Nektarios Leontiadis - leontiadis@cmu.edu<br>Mohammad Baradaran Shoraka - mbaradar@andrew.cmu.edu<br>Chia-Hsuan Yang - chiahsuy@andrew.cmu.edu<br><br>Please note: If you do not wish to receive further emails from us, please click the link below, and you will be automatically removed from our mailing list.<br>http://www.surveymonkey.com/optout.aspx |

**Table 10 Reminder to participate in the survey**

| |
|---|
| Dear FIRSTNAME LASTNAME,<br>We contacted you a few days ago to invite you to complete our on-line survey. Our records indicate that you haven't completed the survey and we would like to request once again that you open the following link and complete it. We only request less than 5 minutes of your time. As a reminder, this survey intends to identify the importance of different aspects of college life (e.g. facilities, faculty interaction) for the improvement of the innovation abilities of the students.<br><br>Here is a link to the survey:<br>http://www.surveymonkey.com/s.aspx<br><br>This link is uniquely tied to this survey and your email address. Please do not forward this message.<br>Thank you in advance, |

Jose Alfredo Galvan - jagalvan@andrew.cmu.edu
Nektarios Leontiadis - leontiadis@cmu.edu
Mohammad Baradaran Shoraka - mbaradar@andrew.cmu.edu
Chia-Hsuan Yang - chiahsuy@andrew.cmu.edu

Please note: If you do not wish to receive further emails from us, please click the link below, and you will be automatically removed from our mailing list.
http://www.surveymonkey.com/optout.aspx

**Table 11 On-Line consent form**

This survey is part of a research study conducted by Jose Alfredo Galvan Galvan at Carnegie Mellon University.
The purpose of the research is to identify the characteristics that a university should have, in general, to develop and boost the innovation capability of its graduates.

Procedures
The participants are expected to answer a number of questions. The expected duration of participation is 5 minutes.

Participant Requirements
Participation in this study is limited to individuals age 18 and older.

Risks
The risks and discomfort associated with participation in this study are no greater than those ordinarily encountered in daily life or during other online activities.

Benefits
There may be no personal benefit from your participation in the study but the knowledge received may be of value to humanity. Compensation & Costs There is no compensation for participation in this study
There will be no cost to you if you participate in this study.

Confidentiality
The data captured for the research does not include any personally identifiable information about you. Your IP address will not be captured.
By participating in this research, you understand and agree that Carnegie Mellon may be required to disclose your consent form, data and other personally identifiable information as required by law, regulation, subpoena or court order. Otherwise, your confidentiality will be maintained in the following manner:
Your data and consent form will be kept separate. Your consent form will be stored in a locked location on Carnegie Mellon property and will not be disclosed to third parties.

By participating, you understand and agree that the data and information gathered during this study may be used by Carnegie Mellon and published and/or disclosed by Carnegie Mellon to others outside of Carnegie Mellon. However, your name, address, contact information and other direct personal identifiers in your consent form will not be mentioned in any such publication or dissemination of the research data and/or results by Carnegie Mellon.

Right to Ask Questions & Contact Information
If you have any questions about this study, you should feel free to ask them by contacting the Principal Investigator now at [Insert the name and title of principal investigator, Department, address city, state, zip, phone number, e-mail address]. If you have questions later, desire additional information, or wish to withdraw your participation please contact the Principle Investigator by mail, phone or e-mail in accordance with the contact information listed above.
If you have questions pertaining to your rights as a research participant; or to report objections to this study, you should contact the Research Regulatory Compliance Office at Carnegie Mellon University. Email: irb-review@andrew.cmu.edu . Phone: 412-268-1901 or 412-268-5460.
The Carnegie Mellon University Institutional Review Board (IRB) has approved the use of human participants for this study.

Voluntary Participation
Your participation in this research is voluntary. You may discontinue participation at any time during the research activity.

1. I am 18 years old or older. (Yes/No)
2. I have read and I understand the information above. (Yes/No)
3. I want to participate in this research and continue with the survey. (Yes/No)

**Table 12 Full survey questionnaire**

4. What is your gender?
- O Female
- O Male

**To be complete, it would be nice to include percents and counts of responses in each category in each quieistion**

5. What is your nationality?
6. How old are you?
- O 20-25
- O 26-30
- O 31-35
- O 36-40
- O 41 or more

7. Which academic program are you attending in CMU?
8. What was your previous major/academic background?

9. Did you have any work experience before joining CMU?

- O Yes
- O No

10. If yes, how many years did you work?

- O 1-5
- O 5-10
- O 11-15
- O 16 or more

11. Have you ever done an internship?

- O Yes
- O No

12. If yes, for how long (months)?

- O 1-2
- O 3-4
- O 5-6
- O 7 or more

13. Are you a graduate student?

- O Yes
- O No

14. In which academic level are you studying at CMU?

- O Masters
- O PhD

15. If it is PhD, have you taken the qualification exams?

- O Yes
- O No

16. Are you graduating within this year?

- O Yes
- O No

17. Do you think the following characteristics are important to be innovative?

Creative approach
Self-driven and persistent
Resourceful and shrewd
Initiator of change
Highly future oriented

18. Do you think the following attributes are important to be innovative?

Challenge Seeking
Persistence
Curiosity
Commitment
Aggressively ambitious

19. Do you think the following values are important to be innovative?

Integrity
Respectful to others
Peace
Freedom
Personal and social responsibility

20. Which kinds of knowledge listed below you think are important to be innovative? Please RANK them all - with 1 being the least important and 5 the most important - and add others if necessary.

Business knowledge (business plan, marketing, market needs, etc)
Technical knowledge (Technology, methods, engineering, production, etc)
Design Knowledge (conceptualization, creativity, form, ergonomic issues, etc)
Law or legal Knowledge (intellectual property, contract, agreement, etc)
Others

21. Do you agree that the contribution of CMU culture is significant for a person's innovation ability?

22. Do you agree that the impact of your academic department's culture is important to promote a person's innovation ability?

23. Following up the previous question:

a. Which part(s) do you think is good?
b. Which part(s) do you think is not good enough?
c. How to improve it?

24. Do you agree that the influence of CMU facilities, like libraries, laboratories, classrooms, gyms and business incubators, are important for improving students' innovation ability?

25. Following up the previous question:

a. Which part(s) do you think is good?
b. Which part(s) do you think is not good enough?
c. How to improve it?

26. Do you agree that CMU faculty skills are important in improving students' innovation ability?

(Choose one option that you think is most suitable and answer the following questions)

27. Do you agree that the effect of academic activities (like seminars, meetings, etc.) in CMU is important in improving students' innovation ability?

(Choose one option that you think is most suitable and answer the following questions)

28. Following up the previous question:

a. Which part(s) do you think is good?
b. Which part(s) do you think is not good enough?
c. How to improve it?

29. Do you agree that the impact of your classmates and/or colleagues in CMU is important in improving your innovation ability?

30. Do you agree that the curriculum in your program has a significant effect in fostering a student's innovation ability?

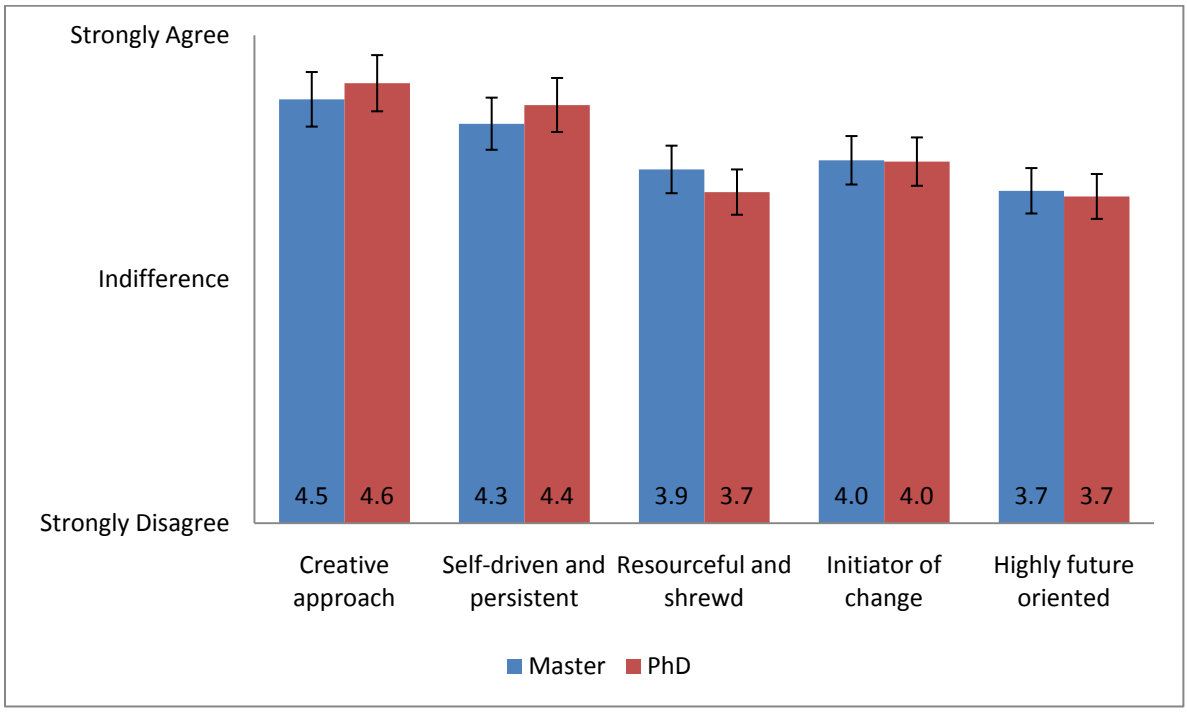
31. Following up the previous question:

a. Which part(s) do you think is good?
b. Which part(s) do you think is not good enough?
c. How to improve it?

*7.2. Part II*

**Appendix A: Academic Level (Master: 40 and PhD: 28)**

Characteristics

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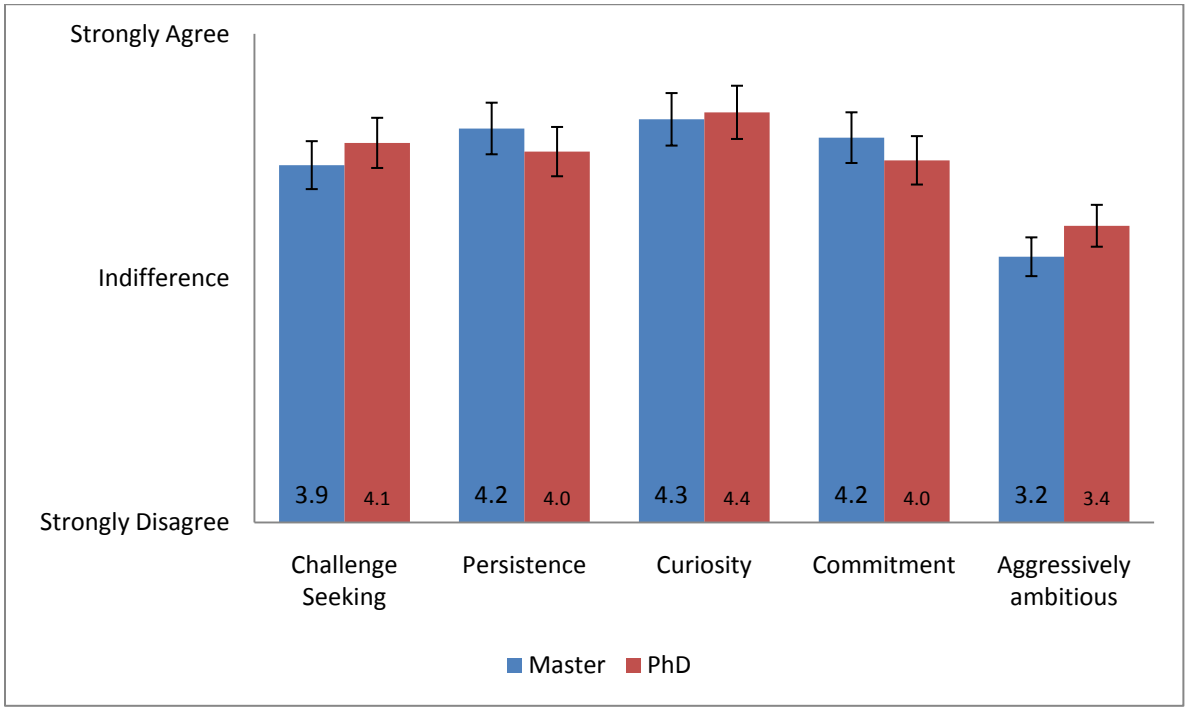


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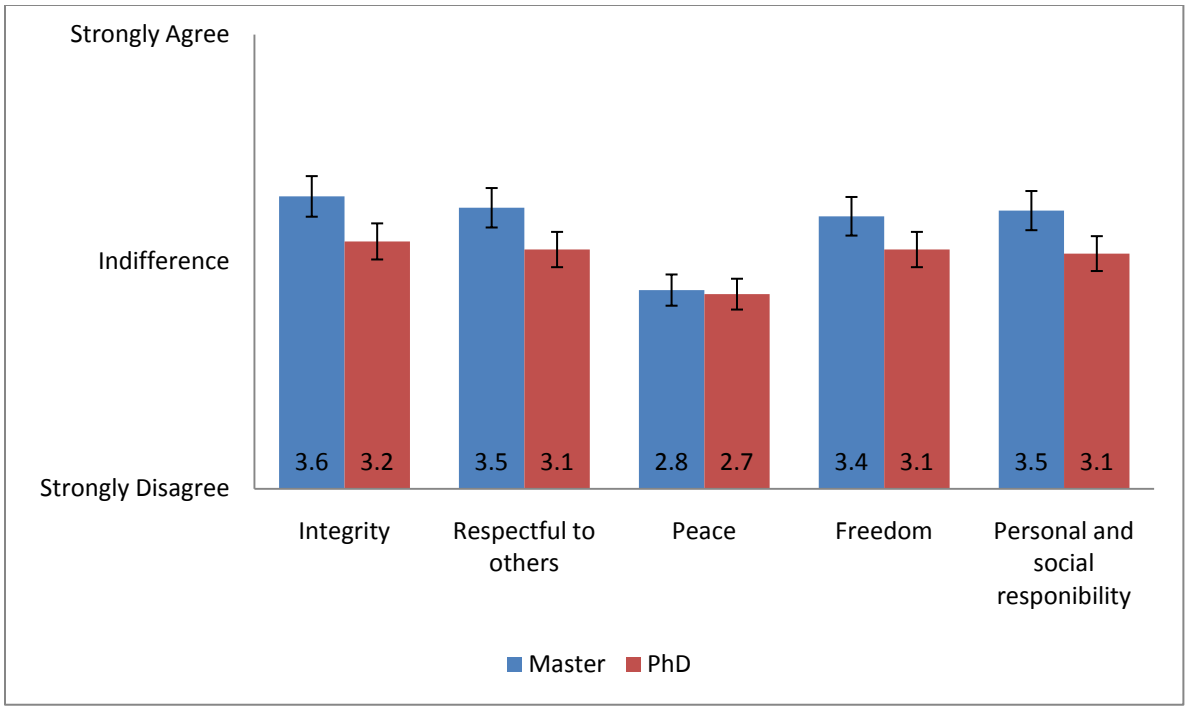
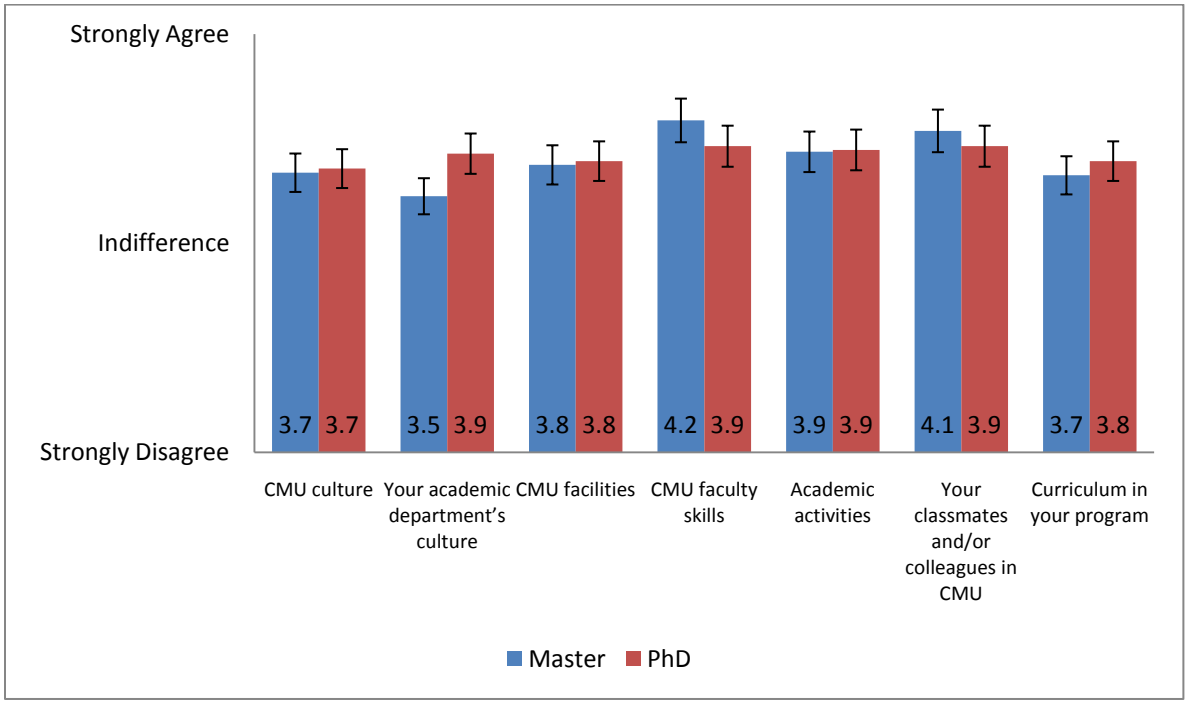



Types of knowledge

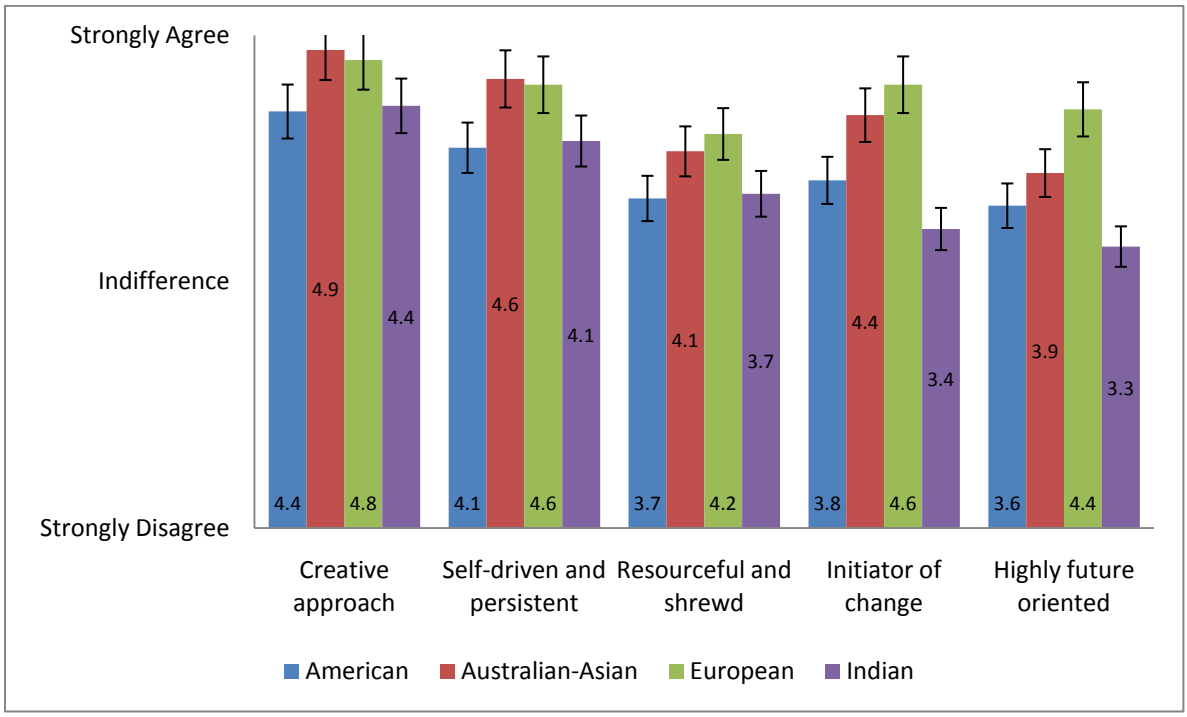
| | Knowledge | | | |
|---|---|---|---|---|
| Region | Business | Technical | Design | Law or legal |
| Master (40) | 3 | 1 | 2 | 4 |
| PhD (28) | 3 | 1 | 2 | 4 |

CMU academic elements



**Appendix B: Nationality (American: 37, Australian-Asian: 17, European: 5, and Indian: 7)**

Characteristics

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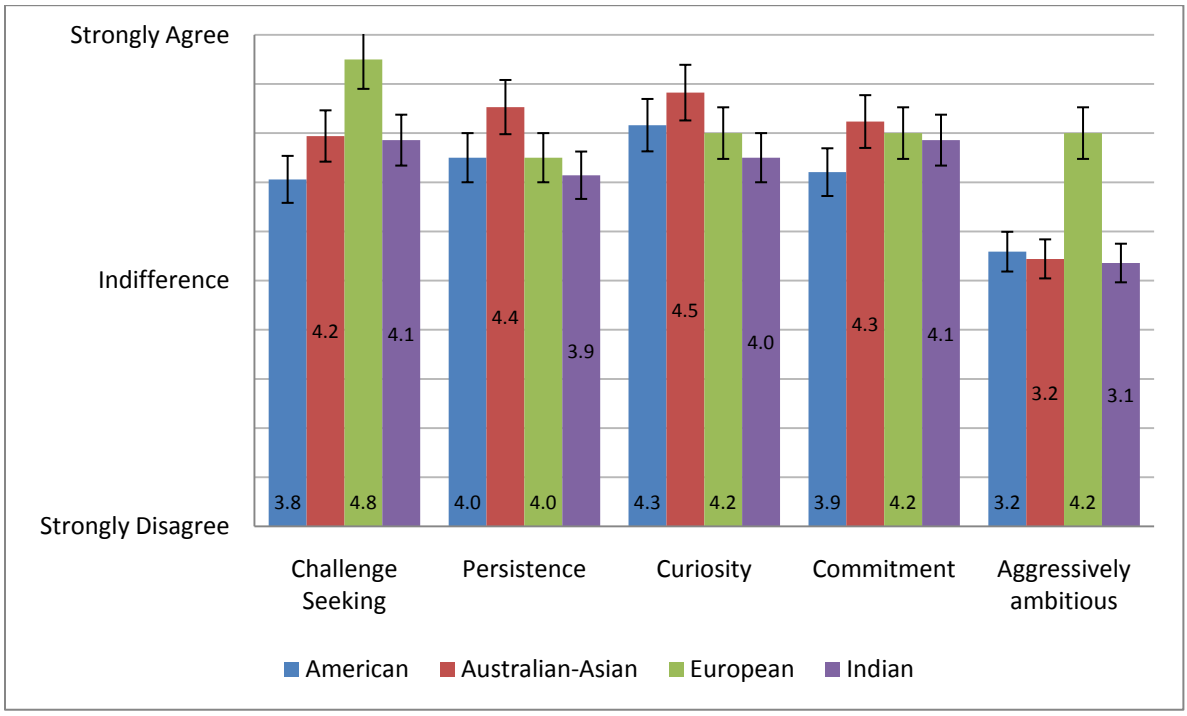

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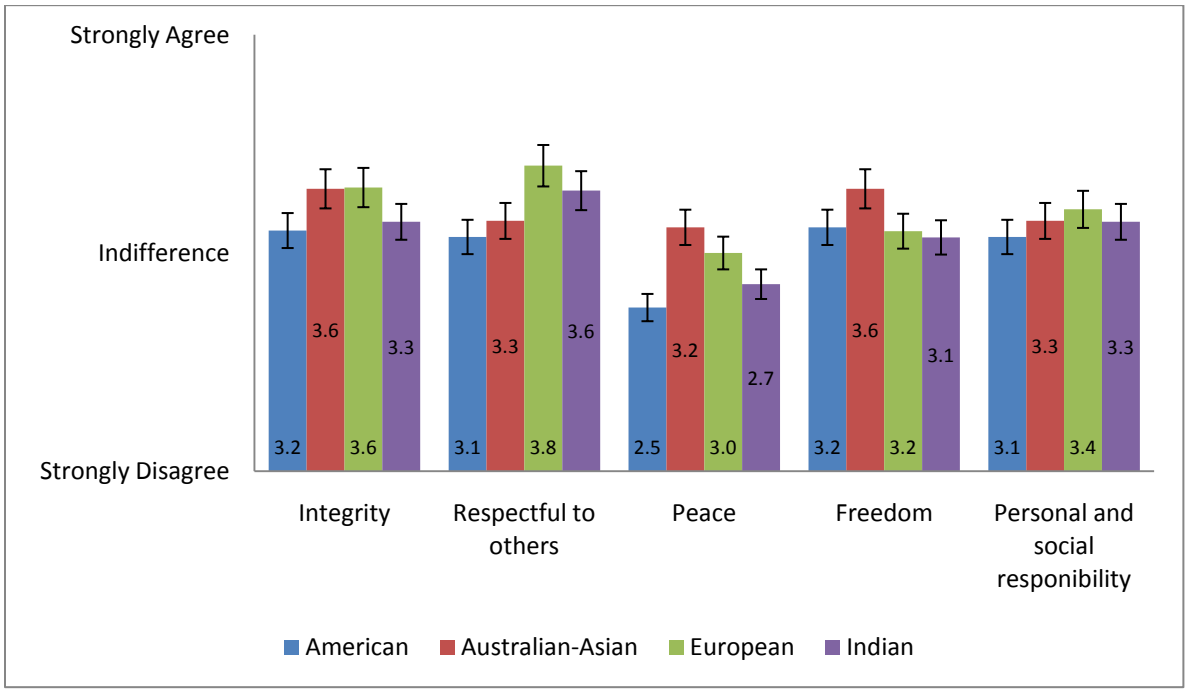
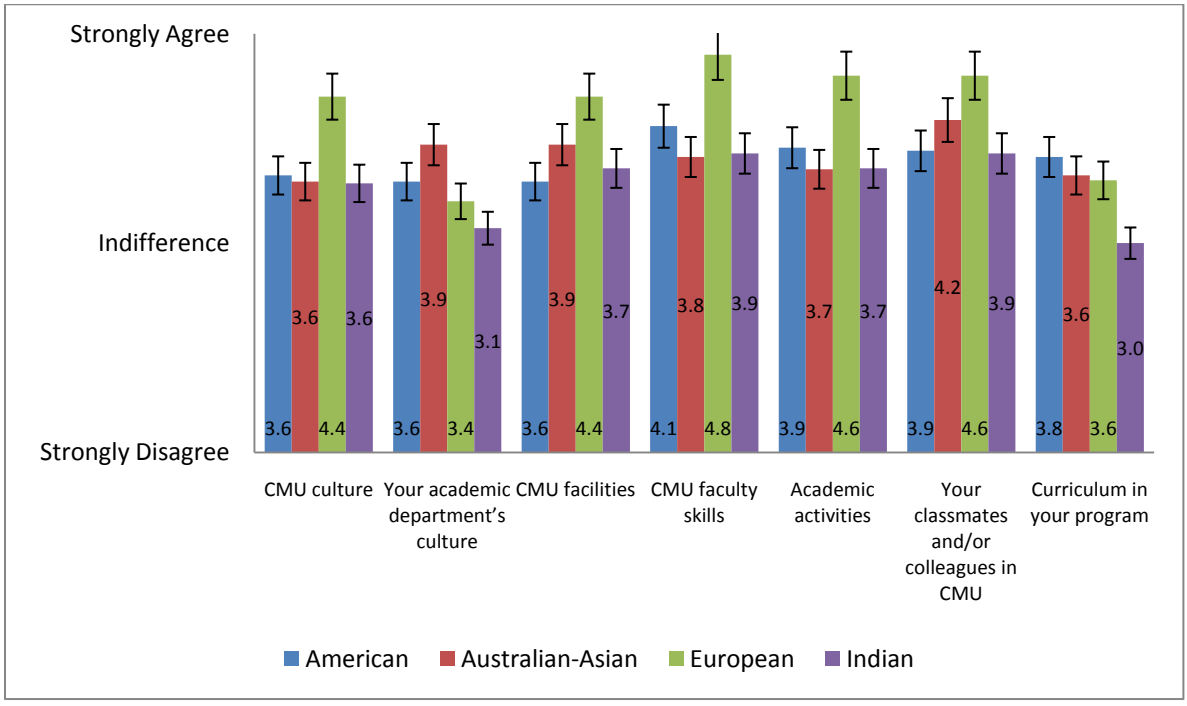



Types of knowledge

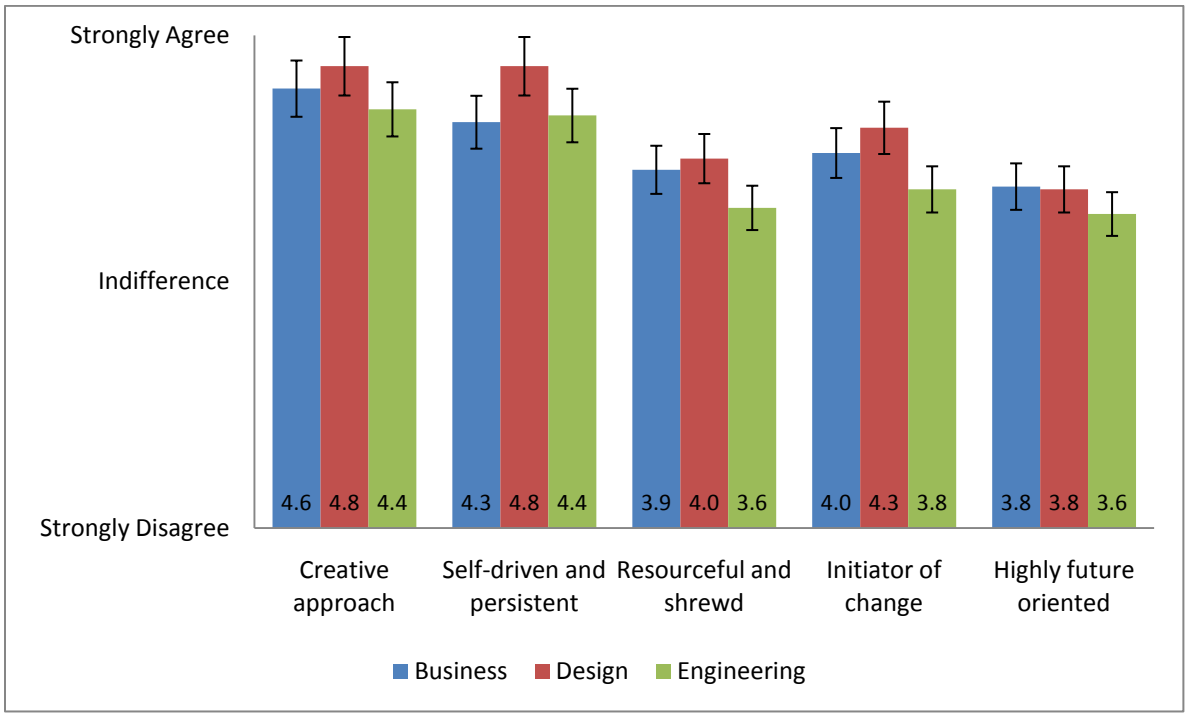
| | Knowledge | | | |
|---|---|---|---|---|
| Region | Business | Technical | Design | Law or legal |
| American | 3 | 2 | 1 | 4 |
| Australian-Asian | 2 | 1 | 2 | 3 |
| European | 2 | 1 | 3 | 4 |
| Indian | 1 | 1 | 2 | 3 |

CMU academic elements



**Appendix C: Schools (Business: 44, Design: 4 and Engineering: 20)**

Characteristics

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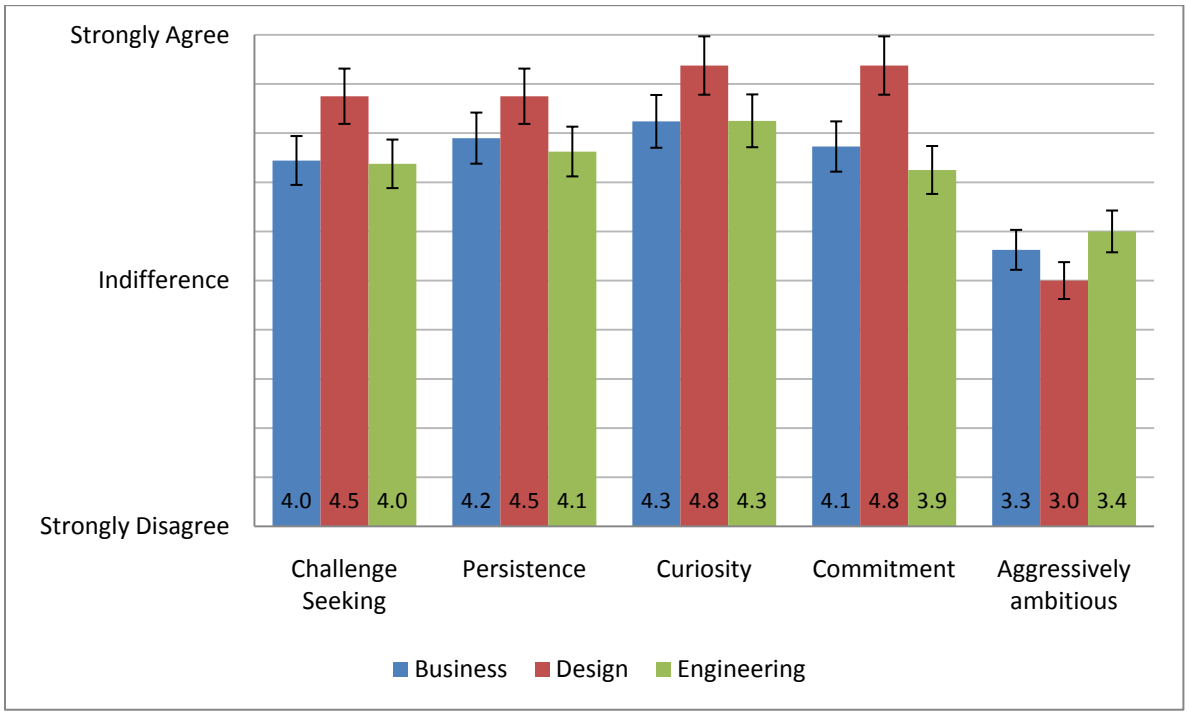

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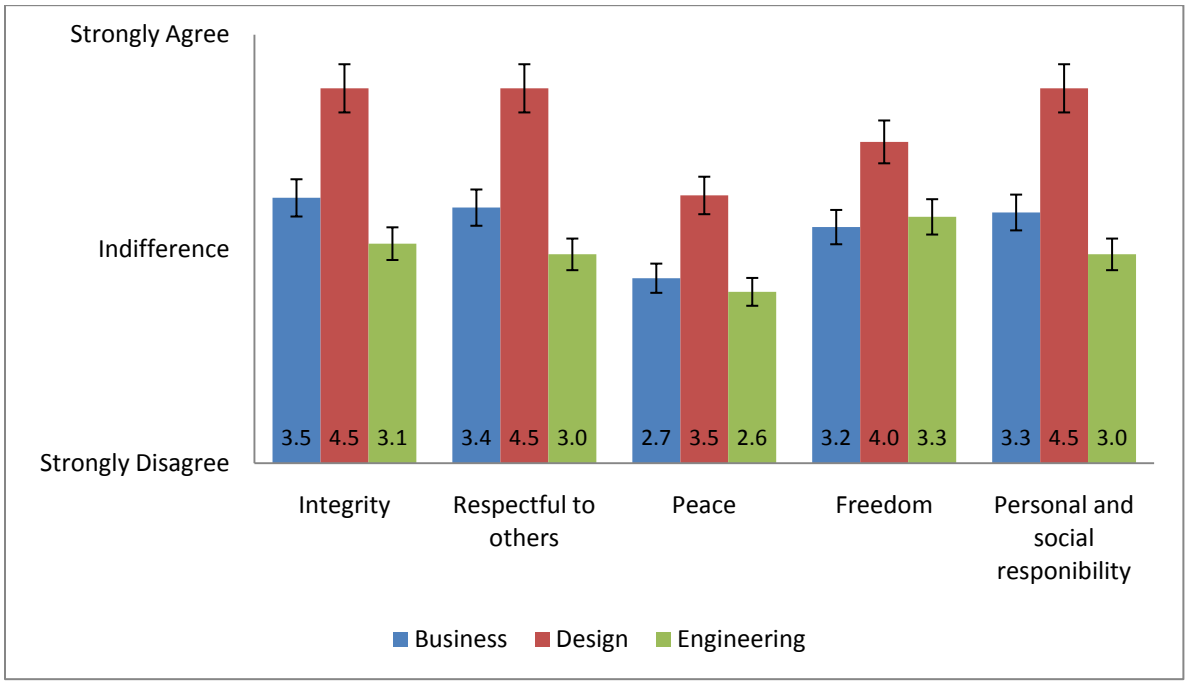
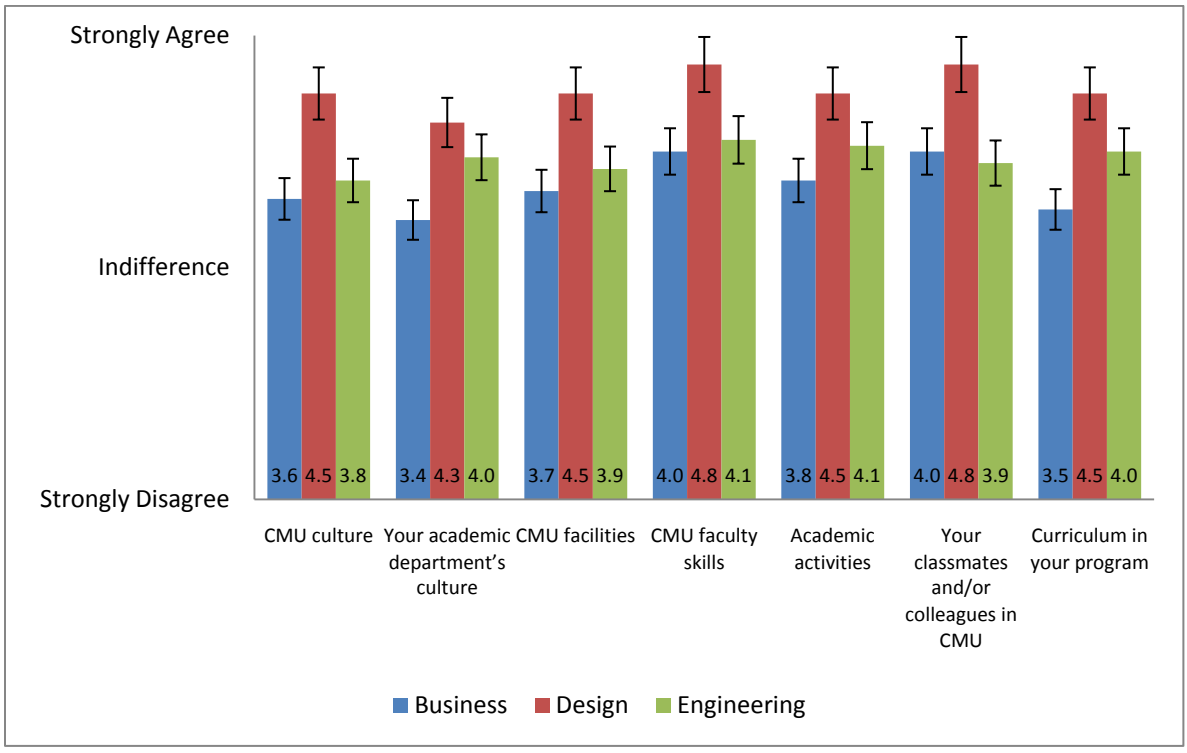



Types of knowledge

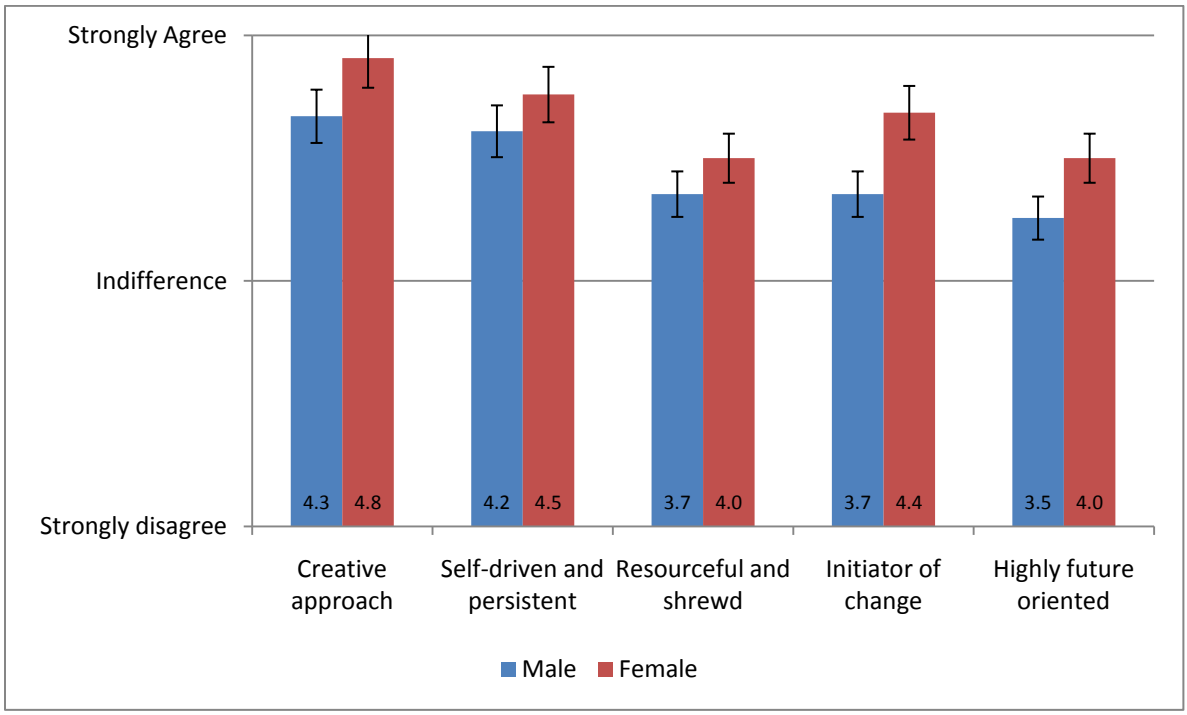
| | Knowledge | | | |
|---|---|---|---|---|
| Region | Business | Technical | Design | Law or legal |
| Business | 1 | 2 | 1 | 3 |
| Design | 3 | 2 | 1 | 4 |
| Engineering | 3 | 1 | 2 | 4 |

CMU academic elements



**Appendix D: Gender (Female: 27 and Male: 41)**

Characteristics

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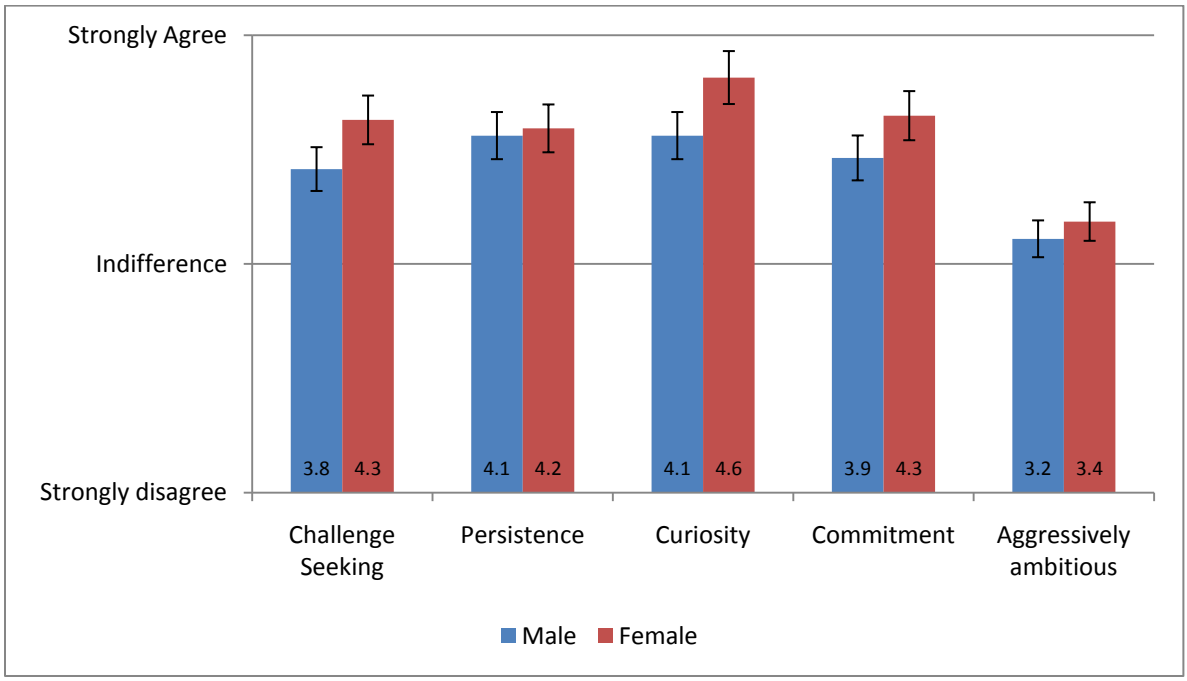

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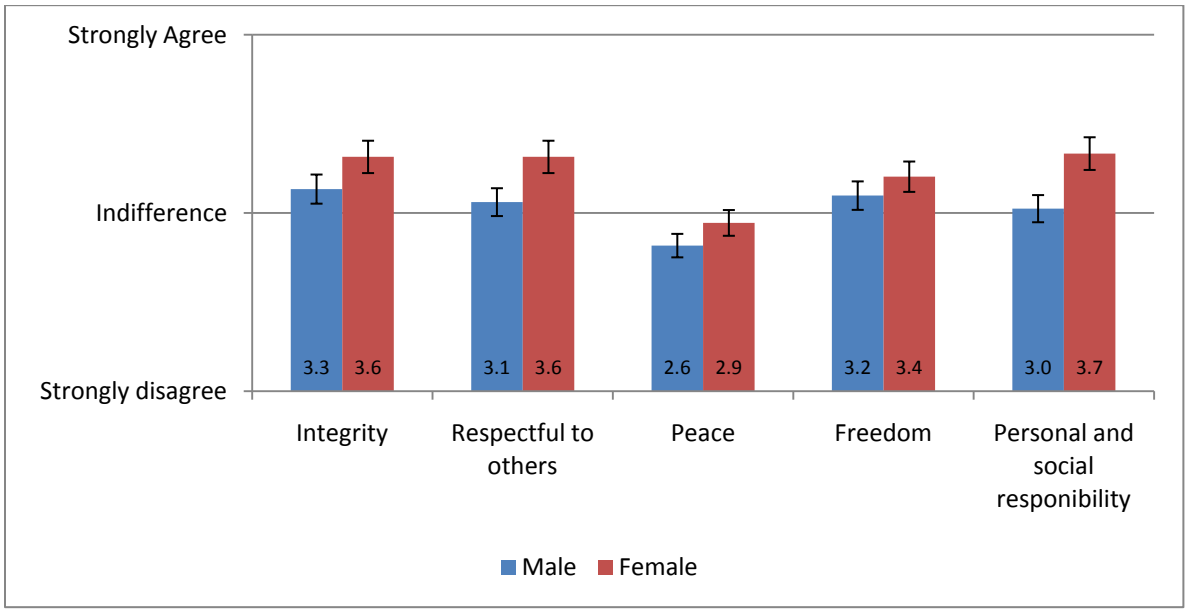
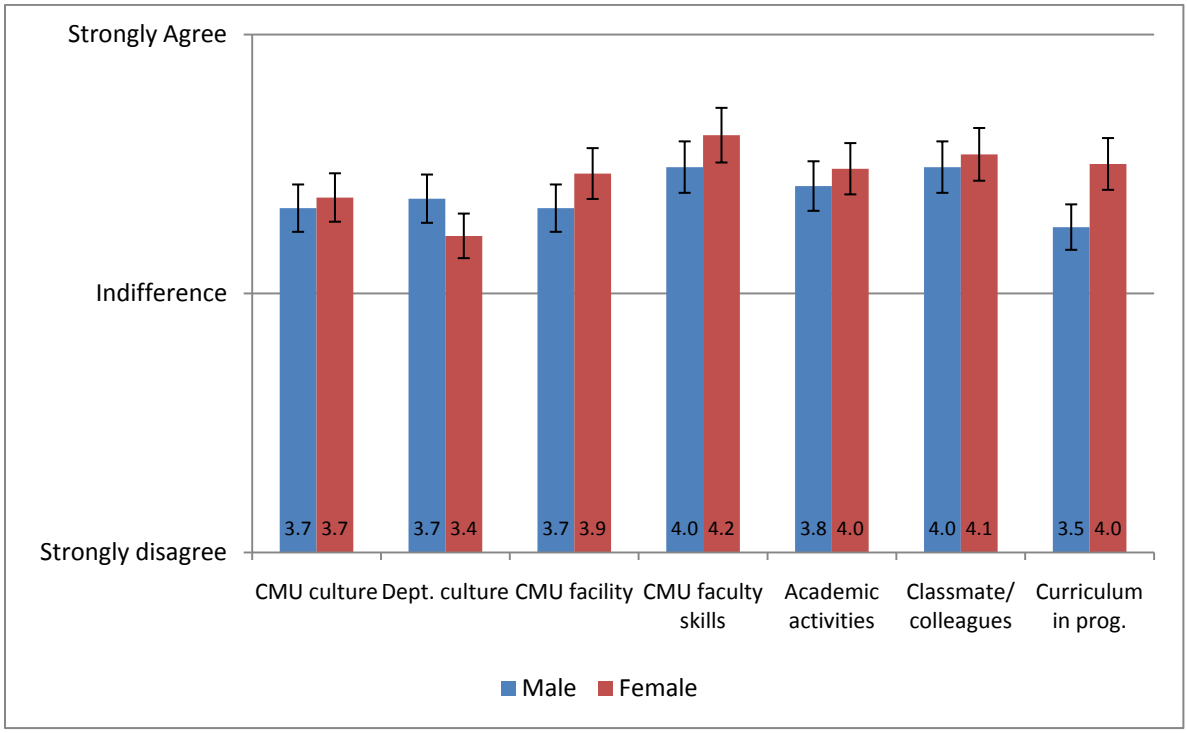



Types of knowledge

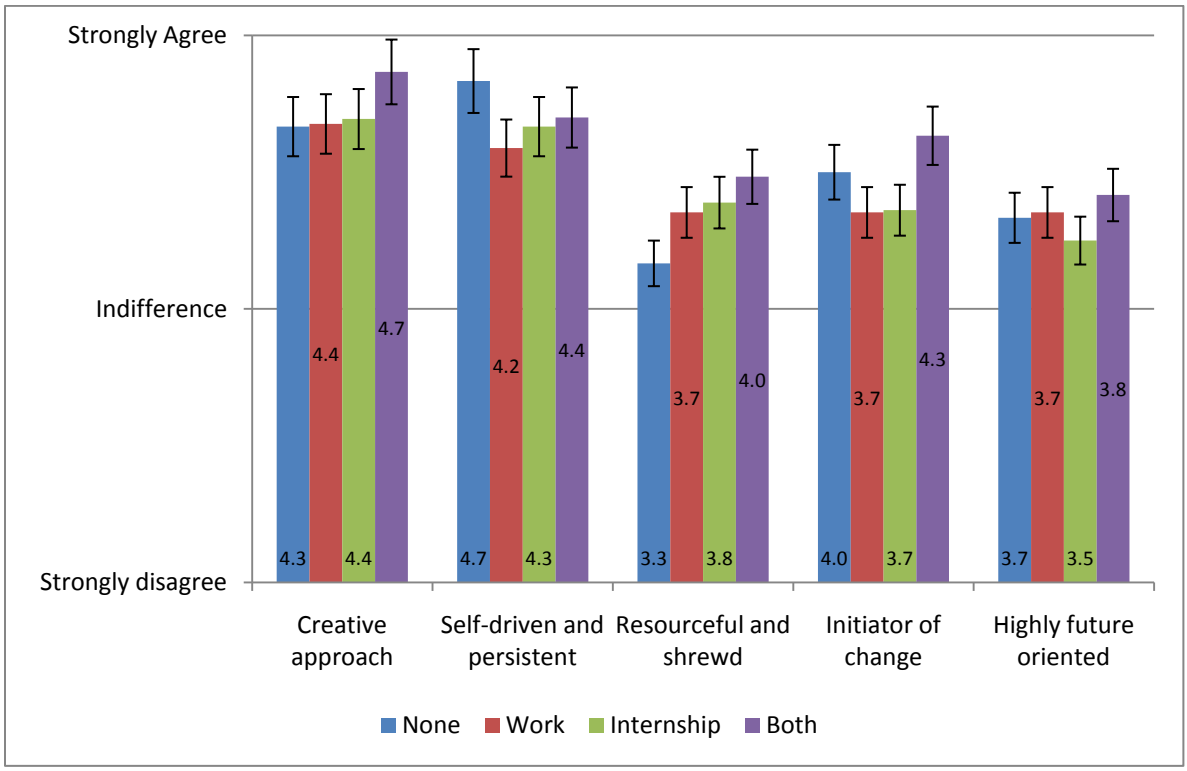
| | Business | Technical | Design | Law or legal |
|---|---|---|---|---|
| Male | 2 | 1 | 3 | 4 |
| Female | 3 | 2 | 1 | 4 |

CMU academic elements

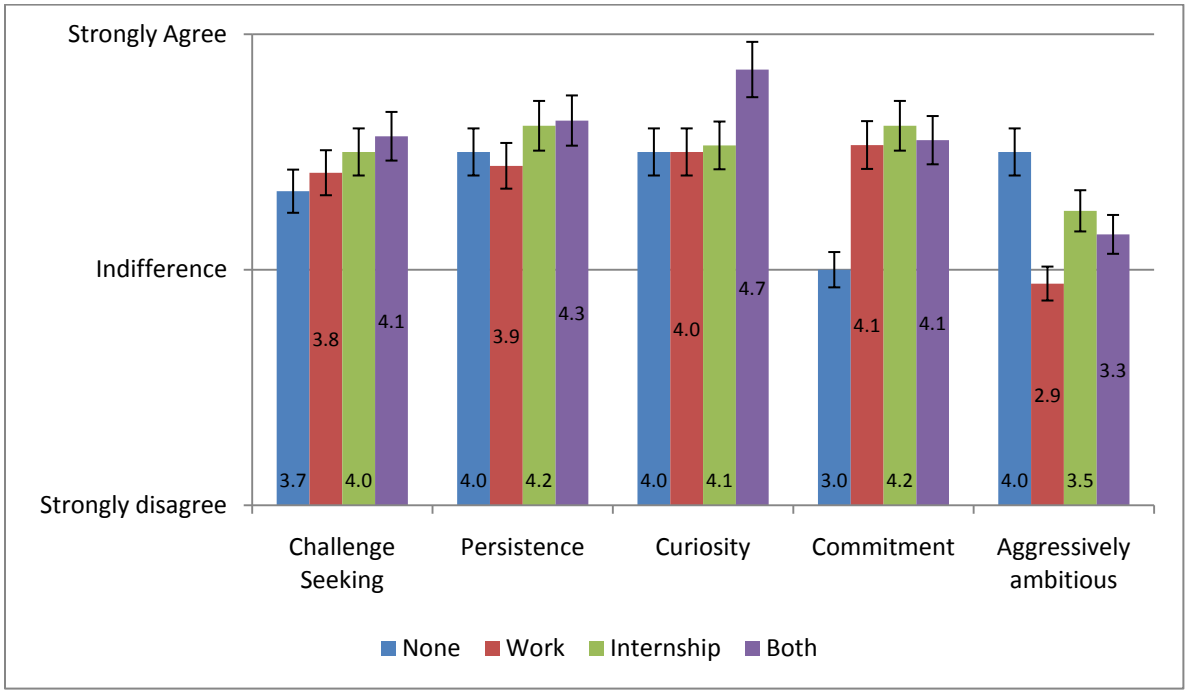


**Appendix E: Internship/Work Experience (None: 3, Work: 17, Internship: 18, and Both: 30)**

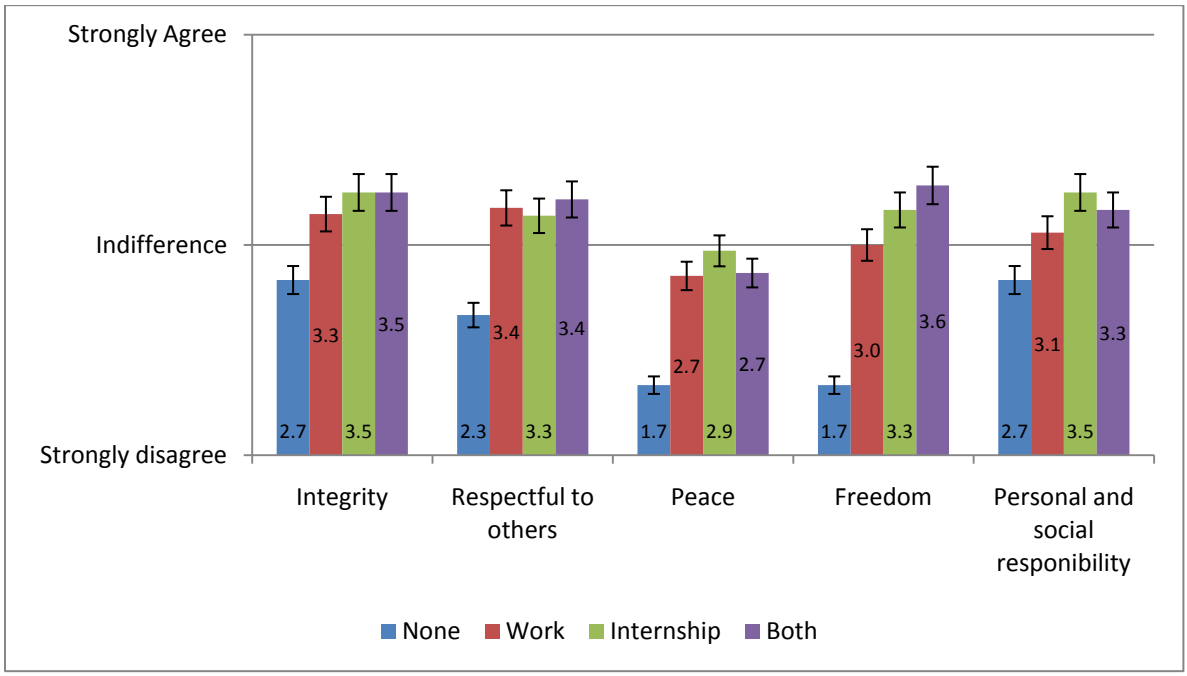
Characteristics




Attributes



Values




Types of knowledge

| | Business | Technical | Design | Law or legal |
|---|---|---|---|---|
| None | 3 | 1 | 2 | 4 |
| Work | 2 | 2 | 1 | 4 |
| Intern | 3 | 1 | 2 | 4 |
| Both | 3 | 1 | 2 | 4 |

CMU academic elements