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STEM Education from the Industry Practitioners' Perspective

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Abstract

This study explores the industry practitioners' perspective on skills required for success in STEM industry professions. Literature review and industry reports indicate that there is an existing gap in the skills acquired by students in STEM majors and the industry expectations of skills. A mismatch in the skills possessed by graduates could result in longer learning curves and decreased employee productivity. The objective of this study is to identify the most important skills desired by industry from college graduates in STEM related fields and add new perspective on STEM education curriculum improvement. The study used a mixed method of both qualitative and quantitative approaches to develop a list of STEM skill indicators and factors. The list of 20 skills was initially identified through qualitative interviews with industry practitioners' and college students. The list of skill indicators were then validated with literature reviews and grouped into 4 factors: Soft skills, Technical skills, and Experience and Managerial skills. The skills and groupings were presented for industry practitioner feedback at a research symposium prior to conducting the quantitative approach of this study. A survey was developed and tested with a pilot group of industry practitioners. The survey was improved in alignment with the feedback received during the pilot study and deployed for data collection. Each identified skill indicator was presented with a Likert scale, for industry feedback on the perceived importance in STEM related industries. The mean value was then used to rank the most important indicators and factors from the industry practitioners' perspective. The rankings and findings of this study are expected to provide valuable information for academics, industry and college students in STEM related fields. The corresponding results can be used to help improve academic curricula, expand college and industry partnerships, and better cater to industry expectations by improving the output quality of college graduates in STEM fields.

Introduction

There is a growing focus and emphasis on education surrounding STEM related technical subjects. STEM education in the traditional sense encompasses education focused on Science, Technology, Engineering and Mathematics. With the projected growth and expansion in STEM industries, there is increased conversation among both academic and industry practitioner communities to enhance STEM education. The focus of improved STEM education is to improve the quality of students who are graduating and entering the STEM work force. It is important that academic institutions invest in the success of students so that they would be impactful and productive employees who are sought after by STEM industry employers. This would improve the reputation of academic institutions among industry and also provide opportunities for increased student recruitment and funding for their institutions. It is not uncommon for colleges to have industry partnerships for research projects and other student mentoring initiatives. But, there is limited conversation with industry on how to strategically improve the academic programs to provide students with the skills desired by industry. This study dives into identifying those skills in order to help integrate a more strategic teaching approach that would help reduce the learning curve for recent graduates, by better preparing them to be efficient and successful employees in STEM industry environments. More recent conversations surrounding STEM education have also recognized the importance of expanding the educational focus of these disciplines to capture a broader set of skills, and have included “Arts” to the STEM focus and rebranded the conversation to be STEAM education. The scope of this study is to identify a general indication of important skills that are desired by industry. Understanding skills viewed as most important from the industry practitioners’ perspective will help advance the quality of graduates and increase industry efficiencies. The objective is to use the findings of this study to provide academics and education institutions with a direction on what focus areas could be improved on to create a more productive and beneficial curriculum for STEM education.

Literature Review

A study in 2013 by Salzman [1] indicated that there seems to be more STEM graduates than jobs available to them in their respective disciplines. The study also indicated that there is a high-tech talent crisis in the United States. This raises the question related to whether there is a real need for STEM graduates, or if there is another underlying problem that has resulted in graduates not receiving jobs in their disciplines. A reason for this could be a mismatch of expectations between the skills acquired by recent college graduates and the skills expected by STEM industry employers. A congressional report published in 2008 discussed concerns associated with a lack of preparation observed in both teachers and students [2]. A possible solution for preventing this lack of preparation of both teachers and students is through making deliberate efforts to improve and enhance partnerships between academia and industry. Initiating conversations and conducting studies surrounding industry practitioner opinions and perspectives can be an appropriate beginning in cultivating these relationships. Labor statistics studies published in 2015 show a projected growth curve for employment up until 2024 for all industries that are closely associated with the construction industry [3]. Many of these type industries are categorized as STEM industries. The reported anticipated growth necessitates the need for generating an adequate supply of productive and competent labor force to meet the growing demands. Increasing the supply of STEM graduates is referred to as a fool’s errand by Macilwan [4]. He expressed the opinion that an increase in the supply of graduates would decrease the current high demand for STEM graduates, and as a result reduce their bargaining power to receive higher compensation for their professional services. It should additionally be noted that if the labor market is unable to cater to the labor needs of STEM industry employers, they may begin to increase recruitment of foreign labor to meet the labor demand. Companies may even uproot operations and relocate to locations that could provide them with the needed labor supply. Therefore, it is vitally important to focus on improving the quality of the labor market.

As a preliminary task in performing this research, a literature review was conducted. This literature review provided the authors with a clear understanding of the skillsets required of successful professionals in a STEM industry. Among skills investigated were traditional soft skills, technical skills requiring competence and or experience, and the ability to work in a team environment. Salleh [5] discussed soft skills in relation to working in teams in a collaborative and cohesive environment, and also further elaborated on the importance of communication for architecture professionals. Another conducted study also listed soft skills, as well as written and oral communication, as important factors in success of higher rank IT Professionals [6]. The same study also highlighted the growing need for IT professionals to not only manage work related tasks, but also manage professional relationships with other colleagues and individuals [6]. The importance of inter-personal skills in team environments was a constant theme addressed by many of the authors.

The importance of maintaining a balance in both technical and interpersonal skills was discussed by Bybee [7]. Kappelman [6] also discussed the significance of technical skills in the context of IT professionals. Translating and effectively communicating these technical skills was referred to as professional writing [8] and workplace writing [9]. The studies discussing technical writing stressed the importance of having continuous training to improve the writing and communication skills of existing employees. These studies also further discussed the necessity for integrating more writing in academic curricula to be better prepare the students for the work environment. Technical skills specifically related to math competency was additionally highlighted in literature [10 & 11] as a factor positively influencing the performance at workplace. Mathematics plays an important role in accuracy and effectiveness of the work performed in many STEM related industries as well as in relation to safety related issues.

Many of the STEM related fields require repetition and practice for improved efficiency [10] and accuracy [11]. Repetition and experience can also be attained through participating in internships and co-op opportunities. This experience will provide the students with a better understanding of the expected role and responsibilities in a work environment [12]. Advanced technologies have also made use of the experiential learning component by providing a hands on learning experience for students in a simulated environment [13]. The exposure to real life and simulated experiences better prepare the students to problem solve. Problem solving was identified as an essential skill for success in Architectural and Engineering related positions[5], as well as in Information Technology related jobs [6]. Industry practitioners and senior managers often discuss the importance of having employees who have the skills to problem solve.

Research Methodology

This research is an extension of a preliminary study of the authors which was conducted in 2016 [14]. The methodology adopted in the 2016 study was based on employing qualitative interviews to identify STEM Skill Indicators. This study also included a quantitative approach involving the determining of mean and rank of the skills presented to industry practitioners through a survey. The initial step of the research process involved a literature review that identified a preliminary list of skills that were highlighted as important for success in STEM related job environments. Next, the researchers scheduled qualitative interviews with both students and industry practitioners to identify a list of skills that were discussed from their perspectives. The skills identified through the qualitative interview process were listed and further evaluated to confirm if there was literature evidence in support of the skills identified during the qualitative interviews. The matrix of skills identified through the qualitative interviews and validated by literature was then compiled for an Engineering and Information Technology research symposium poster presentation, to gather more input and opinions from academics and industry practitioners through a face validity study. The matrix was further refined following the symposium and a research questionnaire was developed to conduct a pilot survey study. The pilot survey study provided additional information that was used to further improve the questionnaire prior to the deployment of the quantitative survey to STEM industry professionals. Once the data was collected, it was analyzed for rankings based on the industry practitioners' highest level of education and the STEM field that they represented.

Data Collection

The qualitative component of this study initiated in 2016, including face to face/phone interviews by the primary author with 8 industry practitioners and 15 students. The selected 8 industry practitioners consisted of individuals with varying positions and experience in STEM affiliated industries. The practitioners interviewed all had Science, Technology, or Engineering background. None of the industry practitioner interviewed identified themselves as Mathematics professionals. The makeup of the students who were interviewed for the preliminary identification of skills are shown in Table 1.

Table 1 – STEM Interviewed Student Demographics [14]

Discipline	Major – Number	Total Students
Science	Nursing Students – 2 Chemistry Students – 2 Biology Students – 1 Exercise Science Students – 1 Public Health Students - 1	7
Technology	IT Students – 4 Computer Science students - 1	5
Engineering	Construction Management Students – 1 Civil Engineering Students – 1 Mechanical Engineering students - 1	3
		Total: 15 Students

The purpose of the qualitative interview phase of the study was for the development of an appropriate survey instrument that could be administered during the quantitative interview phase. This survey was tested with a pilot group of 100 individuals using the Qualtrics survey platform. The data collected from the pilot study was evaluated to make any necessary changes and improvements to the survey. Following the incorporation of appropriate modifications, the survey was distributed to nearly 8,000 STEM industry professionals who were identified through LinkedIn. The survey was kept open for a period of one calendar month and had three programmed reminders that were sent during the survey period.

Qualitative Data and Content Analysis

The participants for the qualitative interviews consisted of industry practitioners who were between the ages of 28–68. The range of industrial experience for these individuals was 2–43 years. Seventy five percent of (or six of the eight) participants indicated that they had at least 15 years of relevant STEM industry experience. The gender distribution of industry professionals who participated in the interviews were 5 males and 3 females. The 15 student participants included a spread of both underclassmen and upperclassmen. The age range of student participants in the qualitative interviews was 18–24 years and the gender distribution of these students was 8 males and 7 females. The skills identified during the qualitative interviews were grouped into a list of STEM Skill Indicators that were linked with the following classified STEM Skill Factors: Soft skills (S), Technical skills (T), and Experience (E) and Managerial skills (M). Table 2 provides a list of identified STEM Skill Indicators with their corresponding STEM Factors and indicates the importance of these skills to the interviewed students and practitioners. The table additionally shows the attributes associated with each skill according to the literature survey conducted.

Table 2 – STEM Skills – Student and Industry Perspectives [14]

Skill Indicator (STEM Factor)	Students' Perspective	Practitioners' Perspective	Attributes used in Literature Survey
Team Work (S)	X	X	"Good team players" [5] "Collaboration" [6]
Communication (S)	X	X	"Confident communicators" [5] "Communication" [15] "Communication (Oral & Written)" [6]
Knowledge Retention (T)	X		"Knowledge Management" [16] and [17]
Accuracy (E)	X		"Calculation Competence" [11]
Empathy (S)	X	X	"Personal skills" [7] "People Management" [6]
Technical Writing (T)		X	"Professional Writing" [8] "Technical Writing" [18] "Workplace writing" [9]
Efficiency (E)	X	X	"Efficiency" [10] and [19]
Analytical Skills (S)	X	X	"Critical Thinker" [5] and [20]
Organization Skills (M)	X		"Organizational Effectiveness" [21]
Competency (T)	X	X	"Technical skills" [7] "Technical Knowledge" [6]
Time Management (M)	X	X	"Time Management" [22], [21] and [23]
Mathematical Skills (T)		X	"Math confidence" [24] "Mathematical Competence" [11]
Internships / Coops (E)	X	X	"Internships and Coops" [25] and [12]
Exposure / Role Play (E)		X	"Simulation/Role-play" [13] "Simulation" [26]
Finance / Accounting (M)		X	"Accounting" [27]
Problem solving (E)	X	X	"Problem solver" [5] "Problem Solving" [6]
Continuing Education (S)	X	X	"Adaptive" [5] "Learning Organization" [15]
Work Ethic (S)	X	X	"Ethics" [28] "Ethical Leadership" [29]
Decision Making (M)		X	"Decision Making" [30]
Business Acumen (M)		X	"ROOT and Business" [31] "Business Analysis" [6]

Quantitative Data and Content Analysis

We received a total of 262 survey responses of which 236 responses were deemed to be valid for the quantitative component of this study. Figure 1 provides a graphical representation of the participants' educational background according to their highest degree earned, while Figure 2 shows the STEM background most representative of their current or most recent STEM related job. As observed, majority of participants had received a bachelor's degree or higher, and had a background in Engineering or Technology.

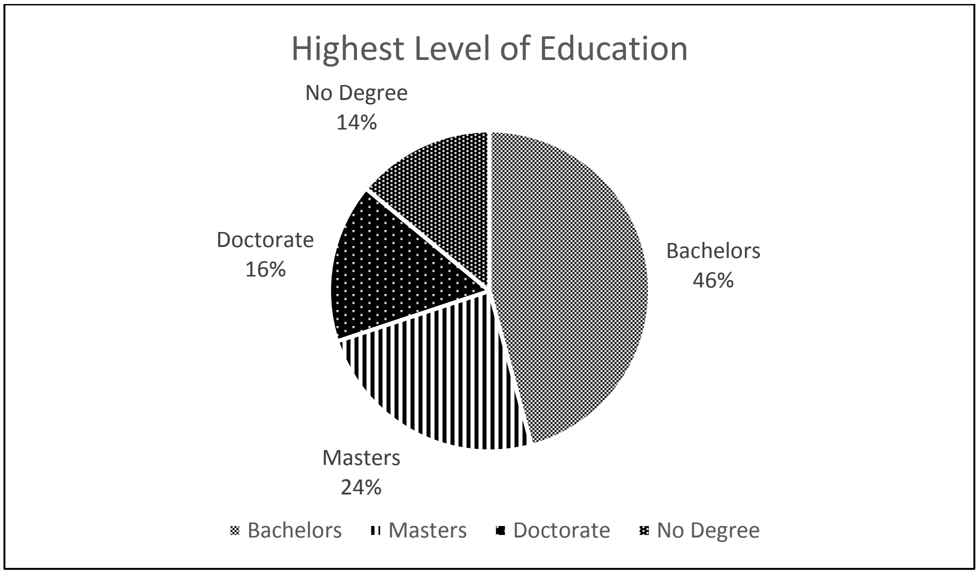

Figure 1. Highest Level of Education

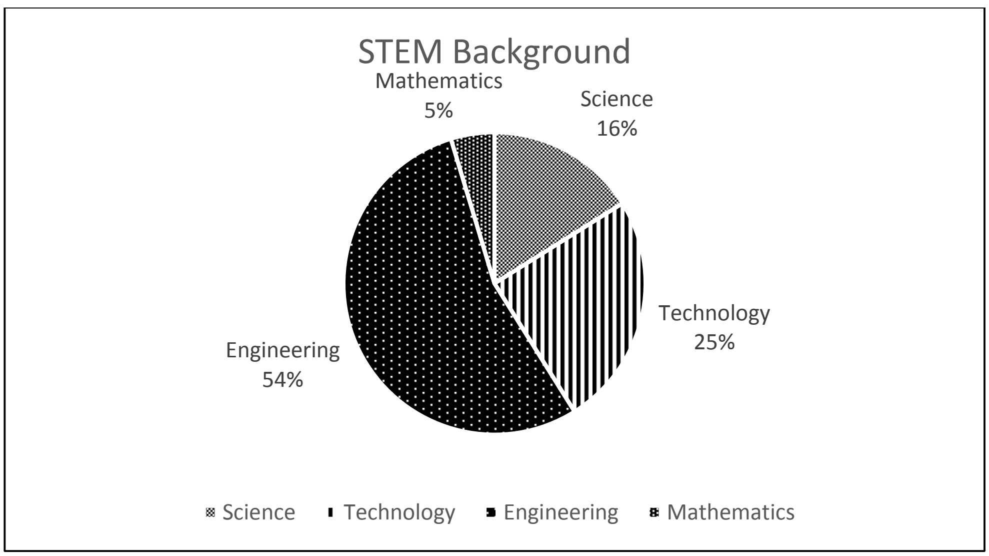

Figure 2. STEM Background of Respondent

Table 3 provides the overall mean score and ranking of each individual Skill Indicator based on the 236 survey responses received. The top ten Skill Indicators identified included: Communication, Work Ethic, Problem Solving, Team Work, Decision Making, Competency, Accuracy, Analytical Skills, Time Management, and Efficiency. Note that five of the ten highest ranking Skill Indicators were Soft Skills. In the top ten list, Managerial and Experiential skills each had two skill indicators, while Technical skills had only one. Table 4 shows the ranking of skills identified in this study by the STEM industry professionals, based on their highest level of education.

Table 3 – Overall Practitioner Ranking of STEM Skill Indicators

Skill Indicator (STEM Factor)	Mean	Rank	Skill Indicator (STEM Factor)	Mean	Rank
Communication (S)	6.35	1	Continuing Education (S)	5.70	11
Work Ethic (S)	6.30	2	Organizational Skills (M)	5.69	12
Problem Solving (S)	6.22	3	Knowledge Retention (T)	5.41	13
Team Work (S)	6.02	4	Business Acumen (M)	5.00	14
Decision Making (M)	6.00	5	Technical Writing (T)	4.94	15
Competency (T)	5.88	6	Empathy (S)	4.79	16
Accuracy (E)	5.86	7	Mathematical Skills (T)	4.77	17
Analytical Skills (S)	5.86	8	Internships / Coops (E)	4.34	18
Time Management (M)	5.83	9	Finance / Accounting (M)	4.08	19
Efficiency (E)	5.72	10	Exposure / Role Play (E)	4.04	20

Table 4 – Ranking of Skills Based on Highest Level of Education

Skill Indicator (STEM Factor)	Bachelors (n=108)		Masters (n=57)		Doctorate (38)		No Degree (n=33)		Biggest Rank Difference
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	
Communication (S)	6.36	1	6.53	1	6.50	1	5.82	3	2
Work Ethic (S)	6.34	2	6.39	2	6.37	3	5.91	2	1
Problem Solving (S)	6.23	3	6.23	3	6.42	2	5.94	1	2
Team work (S)	6.09	4	6.18	5	6.08	4	5.45	10	6
Decision Making (M)	6.04	5	6.14	6	5.92	7	5.73	4	3
Competency (T)	5.82	8	6.05	8	6.03	6	5.61	5	3
Accuracy (E)	5.82	7	6.09	7	5.89	8	5.88	6	2
Analytical Skills (S)	5.80	9	6.19	4	5.79	9	5.58	7	5
Time Management (M)	5.93	6	5.88	12	5.74	10	5.58	8	6
Efficiency (E)	5.73	11	5.89	11	5.68	11	5.39	11	0
Continuing Education (S)	5.50	12	5.91	10	6.05	5	5.58	9	7
Organizational Skills (M)	5.74	10	5.95	9	5.47	12	5.36	12	3
Knowledge Retention (T)	5.39	13	5.51	13	5.45	13	5.24	13	0
Business Acumen (M)	5.11	14	5.19	15	4.58	17	4.76	15	3
Technical Writing (T)	4.70	15	5.39	14	5.37	14	4.45	18	4
Empathy (S)	4.60	17	5.07	16	4.97	15	4.70	16	2
Mathematical Skills (T)	4.64	16	5.05	17	4.66	16	4.82	14	3
Internship/Coop (E)	4.44	18	4.16	18	4.29	18	4.39	20	2
Finance / Accounting (M)	4.00	20	4.09	19	3.89	19	4.55	17	3
Exposure/Role play (E)	4.19	19	3.95	20	3.45	20	4.39	19	1

Regardless of the educational background of participants, Communication, Work Ethic and Problem Solving were ranked among the top 3 Skill Indicators most important for success in a STEM industry profession. The eight Skill Indicators that consistently ranked in the top ten included: Communication, Work Ethic, Problem Solving, Team Work, Decision Making, Competency, Accuracy and Analytical Skills. Time Management and Efficiency were the two skills identified in the overall top ten Skill Indicators, but these were not consistently listed by all educational groups indicated. It was also observed that there is consistency in relation to most of the Skill Indicator rankings, regardless of educational background. The largest rank difference of 7 was noted for Continuing Education, between professionals who had a bachelor's degree and a doctorate degree. The higher the education level, the higher the ranking was for Continuing Education. Technical Writing is often highlighted in classroom environment and there is a large emphasis on this component in academic programs. In spite of this, it was noted that that Technical writing did not receive a ranking higher than fourteen by any of the four educational groups listed.

Communication was ranked as the top Skill Indicator by professionals of all educational levels except for professionals with no earned degree. The top Skill Indicator identified by professionals who had not earned a degree was Problem Solving skill. Participants in the four surveyed educational group, consistently ranked Efficiency and Knowledge Retention at the eleventh and thirteen spots. Team Work was ranked lower by professionals with no degree when compared to professionals who had earned a college degree. Perhaps individuals with college education have a better first-hand experience with learning the importance of team work in a professional environment. Overall, based on industry practitioners' educational background, Soft skills was ranked as the top STEM Skill Factor. Table 5 shows the mean and ranking of skills as identified by industry practitioners surveyed from the four different STEM backgrounds.

Table 5 – Ranking of Skills Based on STEM Industry Background

Skill Indicator (STEM Factor)	Science (n=38)		Technology (n=59)		Engineering (n=128)		Mathematics (n=11)		Biggest Rank Difference
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	
Communication (S)	6.32	1	6.34	1	6.35	2	6.45	1	1
Work Ethic (S)	6.29	2	6.19	3	6.35	1	6.27	3	2
Problem Solving (S)	6.13	3	6.27	2	6.21	3	6.36	2	1
Team work (S)	5.79	11	6.03	4	6.09	4	5.91	11	7
Decision Making (M)	5.97	7	5.98	5	6.01	5	6.09	8	3
Competency (T)	6.13	4	5.80	7	5.82	8	6.18	6	4
Accuracy (E)	6.03	6	5.76	8	5.83	7	6.18	7	1
Analytical Skills (S)	5.87	9	5.95	6	5.80	9	6.09	8	3
Time Management (M)	5.84	10	5.58	12	5.91	6	6.18	5	7
Efficiency (E)	6.03	5	5.61	11	5.65	12	6.18	4	7
Continuing Education (S)	5.95	8	5.71	9	5.69	11	4.91	14	6
Organizational Skills (M)	5.61	13	5.68	10	5.71	10	6.00	10	3
Knowledge Retention (T)	5.68	12	5.42	13	5.29	13	5.73	12	1
Business Acumen (M)	4.45	17	5.22	14	5.14	14	4.27	16	3
Technical Writing (T)	5.00	15	5.08	15	4.92	15	4.00	18	3
Empathy (S)	5.24	14	4.71	16	4.70	17	4.64	15	3
Mathematical Skills (T)	4.82	16	4.44	17	4.84	16	5.36	13	4
Internship/Coop (E)	4.13	19	3.98	19	4.65	18	3.36	20	2
Finance / Accounting (M)	3.92	20	4.29	18	4.06	20	4.18	17	3
Exposure/Role play (E)	4.24	18	3.95	20	4.09	19	3.55	19	2

The provided feedback and rankings from the surveyed STEM professionals indicated that the top 3 STEM Skill Indicators according to their judgement are Communication, Work Ethic, and Problem Solving. This shows that the top 3 ranking Skill Indicators are consistent when analyzed based on both the practitioners' STEM field and their educational background. Similar to the analysis performed based on educational background, the analysis based on STEM disciplines have indicated consistency in ranking from the different groups. The seven Skill Indicators that consistently ranked in the top ten included: Communication, Work Ethic, Problem Solving, Decision Making, Competency, Accuracy, and Analytical Skills. While Team Work, Time Management and Efficiency were identified as part of the top ten Skill Indicators in the overall analysis, it is observed that there is discrepancy between the different STEM disciplines in ranking them among the top ten Skill Indicators. The largest rank difference observed was 7, and interestingly this was for the same three Skill Indicators: Team Work, Time Management and Efficiency. For the Skill Indicators that had the same mean score, the standard deviation was calculated to determine the Skill Indicators ranking. If the standard deviation was also the same, the indicator was given the same rank. For instance, Efficiency, Time Management, Competency and Accuracy all had the same mean score. Therefore, the standard deviation was considered to determine the ranking of these indicators. The indicator with a smaller standard deviation was ranked higher than an indicator with a large standard deviation. Both Decision Making and Analytical skills were ranked the same at eighth place because there was no difference in Mean or Standard Deviation.

Technology and Engineering professionals ranked Team Work as the fourth most important Skill Indicator, while Scientists and Mathematicians ranked Team Work at eleven. This interesting observation may be directly linked to the typical work performed by these professionals based on their industry background. Engineering and Technology professionals are usually in project teams and are exposed to a team work environment. This could possibly be the reason for a higher ranking for Team Work as an important skill. Scientists and Mathematicians are often more focused around teaching, laboratory or other individualized tasks based on their work environments and therefore may not better value the importance of Team Work.

Additional comments in the survey suggested that Emotional Intelligence, Software Skills, Interdisciplinary Thinking and Responsiveness to customer requirements also be incorporated in the study. One participant stated that "Managers should understand the specific skills of employees and learn to delegate and assign work accordingly". Another participant added "Work ethic is sometimes interpreted differently by employers and employees. Employers define work ethic as getting the job done no matter what it takes, and employees seem to define work ethic as being efficient and ethical at work between 9am–5pm". A participant manager stated that "Most importantly, we look out for attitude in any candidate we hire. We hold the philosophy that you hire for attitude and train for whatever the job requires". These statements indicate that there exists a disparity between the employer/manager perspectives and the employee/worker perspectives for professionals working in STEM industries.

Limitations

The findings and interpretation of this study are limited by the scope defined for the study. This study is limited by the number of participants considered and their interpretation of the considered skill sets. For example, Technical Writing may have been interpreted by some respondents as a Communication skill. This study is limited to an overall perspective of practitioners and does not classify them based on factors such as geographic location, culture, or industry specific attributes. The number of participants in the groupings selected for analysis is different and therefore may have an influence on the accuracy of the interpretations.

Recommendations and Conclusion

It is revealed in this study that there is a significant emphasis on the Soft Skills factor highlighted by industry practitioners. Indicators that were linked to the Managerial skills factor seemed to be viewed as the second most important, with Experience and Technical skills factors receiving lower rankings based on industry feedback obtained in the study. This does not mean that Technical or Experiential skills are not considered important by industry practitioner, but there seems to be a perception that Soft skills and Managerial skills play a more important role in industry.

Some stand out observations in this study included a consensus on a significantly lower ranking for the traditionally high ranking math skills in STEM related industries. Additionally, there appeared to be a link in the perceived importance of Team Work if the practitioner had completed a bachelors' degree or higher. Science and Math industry practitioners ranked Team work a lot lower than practitioners in the Engineering and Technology industries. Communication, Work Ethic and Problem solving were highlighted as the three most important Skill Indicators regardless of the practitioners' education or industry background.

It is recommended that future studies consider reviewing and improving the list of Skill Indicators identified by John [14] and further consider formulating analyses dependent on the industry practitioners geographic location, position/title in company, and the number of years in industry. With the evolving nature of technology and processes in industry, it would be prudent to consider these factors when designing instruments for conducting future studies.

For educational institutions, it is recommended that the findings of this study be utilized for strategic improvements in curriculum and course delivery. These findings can provide a guide for incorporating lessons in the students' collegiate work to further help students master the higher ranking skills. The study can also further strengthen the College and Industry partnership through better preparing the students for STEM industry positions. Career centers and advisors in colleges could use the study findings to better guide the STEM students in selecting the proper major and tailoring their skills to the employer needs. A more industry aligned college education will positively contribute to economic growth and creation of jobs.

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