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Examining K-12 Singaporean Parents' Engineering Awareness: An Initial Study of the Knowledge, Attitude, and Behavior (KAB) Framework (Fundamental)

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Abstract

As Singapore looks for more innovative solutions to overcome its geographical constraints and achieve its futuristic modern aspirations, there is a need to produce skilled individuals to address the pressing needs in the critical disciplines of engineering and computer science. To produce such skilled individuals, there is a need to encourage students, starting at an earlier age, to develop and maintain an interest in engineering and ultimately pursue an engineering career. In addition to the role of educational institutions, parents play a pivotal role in encouraging and influencing their children towards certain career paths. Additionally, parents also play an important role in shaping positive attitudes within their children towards engineering, and their supportive actions towards a child's engineering education may help to develop the child's competencies in engineering. Therefore, this current study intends to provide initial empirical evidence of parents' knowledge, attitudes, and behaviors towards engineering disciplines. Our overarching research questions in this study are: To what extent are parents of Singaporean students from primary to secondary levels aware of engineering? And what are the instrument's psychometric properties employed in terms of reliability and correlation among the latent factors in the context of Singapore? This current study uses an empirically validated instrument, the *Parents Engineering Awareness Survey* (PEAS), to examine parents' engineering awareness in their child's engineering education based on the knowledge, attitude, and belief (KAB) framework. The findings of this study aim to raise awareness of engineering education in the Singaporean context from a parents' perspective, which may have consequences for developing an engineering-informed community.

Introduction

Engineering remains key and integral to Singapore's economic, infrastructural, and societal progress (Tan, 2021). With the country committed to sustainable development and combating climate change with the Green Plan 2030, Singapore is in demand of engineers that can help spur research & development and provide innovative solutions to reach Singapore's green goals. Singapore currently faces a shortage of engineering talents (Monk's Hill Ventures & Glints, 2021), and thus needs to find ways to encourage students to enter the field of engineering. Not only does Singapore need to motivate students to pursue engineering, but Singapore must also ensure that graduates from the engineering fields eventually pursue engineering-related careers. Although more than a quarter of graduates in Singapore are from the engineering sciences, engineering remains one of the top two sectors that faces the greatest difficulty in hiring (Lim, 2019). Lim (2019) attributes this to engineers choosing professions out of the engineering-related fields.

While there are numerous efforts in Singapore to increase interest in engineering, there is no specific, dedicated engineering-focused curriculum being embedded in the pre-college curriculum in Singapore. Instead, there are supplementary holistic programs (e.g., the Applied

Learning Program) provided by the Ministry of Education (MOE, 2018) to promote authentic and practice-oriented learning in STEM domains for students. All these efforts aim to increase the acquisition of knowledge and skills in STEM fields. In addition to existing efforts, it is still worthwhile to understand other factors that influence students and determine what more can be done to develop engineering interest and behavior in students (e.g., Burley et al., 2016; Youngblood et al., 2016; Yeter et al., 2016). One of the factors that can be looked into is the role of parents. Parents play an integral role in influencing students' career choices, helping them develop engineering traits, providing motivation for students to succeed academically, and helping them with the learning process (Dorie et al., 2014). Naturally, a stronger parental influence on engineering can encourage more students into the engineering field.

By gaining insights into parents' perceptions of engineering, we can improve teaching and learning in engineering. Understanding parents' perceptions allows us to better understand a student's profile based on their background and how parents should interact with educators and the school (Yun et al., 2010). Such information can be used in two ways: (a) to inspire students to pick engineering-related courses when making decisions on their post-secondary and tertiary education; and (b) to design teaching and learning environments that help to sustain student interest and facilitate the acquisition of behavioral traits that sustain interest in the field, even after graduation. Furthermore, such information provides insights into what steps can be taken by schools, educational institutions, and policymakers to improve engineering education by working with parents. Schwiderski (2018) found in her multiple regression study between first-generation and non-first-generation college students that while first-generation students may receive support from their parents, the support is usually general and does not help prepare them for college. Thus, this may result in a difference in success between first-generation and non-first-generation college students. Additionally, while the study of Venkatesh et al., (2022) provides the preliminary findings, it suggests that first-generation engineering students accumulated higher mean scores on the tinkering, perspective taking, and reading people compared to the continuing generation engineering students in Singapore. However, due to the lack of research and empirical data about parents and engineering education in Singapore, this study aims to gather empirical data regarding Singaporean parents' awareness of engineering based on the knowledge, attitude, and behavior (KAB) framework at the primary through secondary school levels. Furthermore, this study includes the validated parents' engineering awareness survey (PEAS) developed by Yun et al. (2010). The survey looks at parents' perceptions of engineering in accordance with the KAB framework and separates its items specifically to the individual domains of knowledge, attitude, and behavior. In this scope, the overall research questions are:

1. To what extent are parents of Singaporean students from primary to secondary levels aware of engineering?
    a. Is there any significant difference between subgroups (e.g., gender, educational background) with respect to the latent factors of the instrument employed?
2. What are the instrument's psychometric properties employed in terms of reliability and correlation among the latent factors in the context of Singapore?

KAB Framework

The domains of knowledge, attitude, and behavior (KAB) were developed from Bloom et al.'s (1956) study on developing instructional learning objectives for teaching and learning, from the initial domains of cognitive, affective, and psychomotor. The KAB framework is often used in medical research to show that the three domains are interrelated—with knowledge and attitude affecting behaviors eventually (Liu et al., 2016). Though the framework was initially introduced in the medical literature on the topic of primary care for AIDS (Miller et al., 1990), it can still be applied to the educational sciences, and the interrelatedness between the three domains still applies in the field of educational sciences (Yun et al., 2010). Research has shown that knowledge relevance strongly impacts attitude-behavioral consistency (Fabrigar et al., 2006). Similarly, people tend to follow their attitudes about the willingness to expand and extrapolate their knowledge and adopt behaviors.

The intricacy of the KAB framework offers a more holistic insight into the "cognitive constructs associated with development and change" (Schrader & Lawless, 2004). The KAB framework can accept the complexity of the educational learning environments— which elementary evaluations cannot analyze in totality. The KAB framework extends beyond just the constructs of knowledge acquisition and encompasses the idea that all three domains are interrelated and are integral factors in affecting change. Thus, this makes it a powerful evaluator for any form of interventional strategies in the education domain.

Knowledge

Knowledge is a core component of Bloom's taxonomy under the area of cognitive processing. In Bloom's taxonomy, the cognitive process looks at how much one knows the facts and skills of a relevant field and how they contribute to the understanding. In epistemology, knowledge is one of the core concepts of the field. Knowledge can be classified into three forms: (1) knowing individuals, which comes from being acquainted with the individual, and this extends to places and objects (2) knowing how, also known as procedural knowledge, and (3) knowing facts, which look into understanding the "what" and "why" (Steup & Neta, 2020).

Knowledge allows people to construct new knowledge from a new piece of information, such as making inferences and connecting pieces of information together (Gagne et al., 1993). Social constructivist theory in learning (Vygotsky, 1978; see also Gauvain, 2001; Sutinen, 2008) also emphasizes the role of interactions between the learner and the environment and individuals around him. Beyond acquiring new knowledge, experience allows an individual to place added attention or diminished focus on their surroundings (Tan, 1996).

In the survey, knowledge indicates the parents' general understanding of the notions and principles of engineering (Yun et al., 2010). Knowledge comprises the parents' understanding of the general themes within the engineering field or their understanding of the presence of engineering in their children's schooling. An example of an item under the knowledge domain is "I know how to find out more about engineering information to help my child(ren)'s learning."

Attitude

Past research outlines two key frameworks that could be used to define the concept of attitude: the behavioral framework and the cognitive framework (Schrader & Lawless, 2004). The behavioral frameworks that were outlined by Allport (1967, as cited in Schrader & Lawless, 2004) and LaPierre (1967, as cited in Schrader & Lawless, 2004) defined attitude as a mental state of readiness that arises due to earlier conditioning by a stimulus. In other words, an individual will respond to objects that are related to the stimuli. Meanwhile, through the cognitive framework, Thurstone (1967, p. 261, as cited in Schrader & Lawless, 2004) defined attitude as “the effect for or against a psychological object," rather than towards a behavioral object. Additionally, Thurstone (1967, as cited in Schrader & Lawless, 2004), posits that attitudes are subjective since they can be regarded as the summation of all emotions and sentiments towards a specific notion, belief, or action.

The scope of attitude has been expanded further in recent times by psychologists to include three components: cognitive, affective, and conative (e.g., Ajzen, 1993; Erwin, 2001 as cited in Schrader & Lawless, 2004). The breakdown of these three components by Schrader & Lawless (2004) are; (1) the cognitive component, referring to the beliefs or sentiments that are related to a certain psychological entity, (2) the effective segment of attitude is a person’s judgment of the psychological entity and the corresponding feelings evoked by the entity, and finally, (3) the conative component (also known as the behavioral component) of attitude represents an individual’s alleged actions or tendencies toward performing that action that is directed towards the object. Relating to the affective domain specified by Bloom (1976), this domain may involve both the affective and conative components, as it represents one’s emotional reaction to some action or behavior.

Considering the varied definitions of attitude presented, attitude in this study refers to parents’ beliefs and emotions towards engineering. An example of an item under the attitude domain is “I think it is equally important for girls and boys to learn engineering.”

Behavior

Behavior is something that an individual or group does that is directly measurable and can be observed (Tan et al., 2017). Many researchers adopt a similar definition of behavior as to how an individual, organism, or group reacts to certain conditions (Schrader & Lawless, 2004). As an individual’s responses to different stimuli can change over time, much research in education looks to change negative behaviors and nurture positive behaviors within the student (e.g., Belfiore & Hornyak, 1998; Glenzer, 2005; Skinner, 1953).

Multiple techniques have been used to record and study behavioral patterns. Schraeder & Lawless (2004) summarized the different methods that had been used across the literature, including “direct measurement techniques,” which refers to recording the frequency at which a specific action has taken place, and “less direct methods” which means eliciting information from other individuals that are in close contact with a participant to glean greater insight into the dynamics of the participant's behavior; and finally “other less direct methods,” referring to reflection done by a participant through different forms of self-report.

In this survey, the domain of behavior refers to the frequency of the actions that parents carry out with their children to support engineering. An example of an item in the behavior domain is “I encourage my child to identify and solve problems.”

Methodology

Data Collection

The participants of this study were parents, guardians, and primary caregivers of students in K12 schools, who are between the ages of 21 and 60, and reside in Singapore. As the term K-12 is not used in the local Singaporean context, the education levels of primary to secondary schools were selected based on the age groups (7–17 years old) that corresponded to K-12 education levels. Thus, the inclusion criteria for participants in the study are (1) primary caregivers (parents or guardians) of students in Singapore primary and secondary schools, (2) between the ages of 21 and 60, and (3) who live in Singapore.

Participants were recruited through the personal contacts of the student researchers. Subsequently, more participants were contacted through snowball sampling, in which existing subjects of the study recruited other participants. Gender, ethnicity, race, and socioeconomic status of participants were collected, despite being determined not to be key criteria/characteristics that may affect the targeted study group.

After obtaining the necessary ethical procedures (e.g., IRB), student researchers posted an invitation to participate in the survey via various social media platforms. A consent form was then sent out through email detailing the specificities of the survey process, the aims of the study, as well as a confirmation to participate willingly, and was completed by the interested participant. Participants were informed that the duration of the study would take approximately 30 minutes to an hour and how their data would be used. This form was sent back to the student researcher before the participant proceeded to complete the survey. At any point, should the participant be uncomfortable, he or she can withdraw from the study. No incentives were provided for participation in the study. The online survey has three parts and was completed by 32 parents residing in Singapore.

Instrumentation

The PEAS survey comprises 48 items, with 16 items for the knowledge component, 20 items for the attitude component, and 12 items for the behavior component. The PEAS survey by Yun et al. (2010) was already empirically tested to be reliable. In the development of the survey, the survey was found to have a high Cronbach’s Alpha of 0.94, 0.91, and 0.84 for the items in each of the components, respectively. The survey uses a 5-point Likert scale, with the first two components measuring the participants' agreement with the statements on knowledge and attitudes, respectively. For the behavior component, a similar 5-point Likert scale is used, although the scale measures the frequency of the parents' carrying out the activities in each item. The advantage of a Likert scale is that participants are not forced to have a stand on the statements under each item and are given an option for neutrality. It also allows parents to express the extent of their agreement on the different items, as opposed to a mere yes or no answer. The use of the Likert scale would make it easier to code for each participant’s response as a number is associated with every answer. The use of the Likert survey is also quick and efficient for the participants.

The survey used in this context has been slightly modified to fit the Singaporean context. The demographic information was changed since income stratification in Singapore is more stratified by monthly income instead of yearly income as per the original survey (Singapore Department of Statistics, 2020). Furthermore, the term “race” is also used in official classification in Singapore instead of “ethnicity.” Another change that was done to the survey was the frequency was changed to cover a larger spectrum of frequency and reduce the ambiguity that may arise from the wording of the original PEAS survey. The Likert scale for this study used would be "1 = Never, 2 = 1-3 times a year, 3 = 4-11 times a year, 4 = About once a month, and 5 = At least once a week”. This replaces the original Likert scale that was used in the PEAS survey: “1 = Never, 2 = Less than once a year, 3 = About once a year, 4 = About once a month, 5 = At least once a week.”

Data Analysis

For the data analysis, we checked the skewness and kurtosis coefficients of each item. To assess construct reliability, we used Pearson’s correlation to verify the intensity of the existing linear association between variables, and it measures the linear association between quantitative variables. Furthermore, to determine the instrument’s internal consistency in terms of reliability, Cronbach’s alpha was calculated for the existing correlation between each item in the three constructs. To examine the instrument’s internal reliability, Cronbach’s alpha was calculated for the items in each of the constructs. Additionally, we ran a series of Mann-Whitney U tests using SPSS (v 28) to compare the variables of gender, age, educational background, household income, and interaction with engineers with each construct. The Mann-Whitney test was chosen due to the small sample size of this study, despite some variables meeting the normality condition. Additionally, this non-parametric test yields more conservative, and thus accurate, results compared to other parametric tests, such as the independent sample t-test.

Results

To answer research question 1, Pearson’s correlation analysis revealed a moderate positive correlation among the three constructs. The r-value for the knowledge scale and attitude was .421 ($p = .016$), the r-value for knowledge and behavior was .574 ($p < .001$), and the r-value for attitude and behavior was .586 ($p < .001$). As shown in Table 1, the instrument had high reliability and internal consistency, as indicated by the high Cronbach alpha scores of the knowledge scale, which consisted of 16 items ($\alpha = .944$); the attitude scale, which consisted of 20 items ($\alpha = .909$); and the behavior scale, which consisted of 12 items ($\alpha = .928$).

Table 1. *Reliability result of each KAB construct*

	Knowledge (N = 16)	**Attitude (N = 20)**	**Behavior (N = 12)**
Cronbach’s alpha	0.944	0.909	0.928

To answer research question 2, as shown in Table 2, the Mann-Whitney U test was conducted to compare the variable of gender with the three constructs. The results of knowledge scale scores indicated significant differences between the two groups (i.e. female participants and male participants), (U = 173.500, p = .021). Thus, the null hypothesis can be rejected and we can conclude that there is a difference in the knowledge scale between males and females. No significant differences were found between male and female respondents on both the attitude scale and behavior scale, (U = 111.500, p = .874) and (U = 114.000, p = .952) respectively.

The Mann-Whitney U test was also conducted to compare the variable of age with the three constructs. We found no statistically significant differences between participants aged 40-49 and those aged 50-59 in knowledge (U = 124.500, p = .861), attitude (U = 112.000, p = .755), and behavior (U = 87.500, p = .205). However, results revealed that participants aged 40-49 had a higher aggregated score in attitude and behavior, compared to those aged 50-59.

The Mann-Whitney U test used to compare the variable of educational background revealed no statistically significant differences between participants' education level and the three constructs. Interestingly, on an aggregated score, participants in the group "bachelor and below" had higher aggregated scores for all three constructs, compared to participants in the "postgraduate" group.

There were also no statistically significant differences between participants with a lower monthly household income ($8000 and below) and those with a higher monthly household income (more than $8000), with regard to knowledge (U = 146.000, p = .484), attitude (U = 104.000, p = .374), and behavior (U = 116.000, p = .664). Specifically, participants with a higher monthly household income scored higher, on an aggregated score, for the constructs of knowledge and behavior.

With regard to parents' interaction with engineers, there was a significant statistical difference in knowledge (U = 47.500, p = .003) and behavior (U = 62.500, p = .016) scales, between parents who had greater opportunities to interact with engineers and parents who did not. There was no statistically significant difference with respect to attitude between these two groups.

Overall, the data analysis revealed that the instrument had high internal validity and that there existed a moderate positive correlation among the three constructs of knowledge, attitude, and behavior. The data analysis also revealed no significant statistical differences were found between age, educational background, and monthly household income across all three constructs. However, it should be noted that the lack of significance in many of the findings is likely due to the small sample size of this study. Therefore, future studies should involve a larger number of participants to verify the results of this study.

Table 2. *Summary of results from the PEAS survey*

	N	Mean (SD)	Skewness	Kurtosis	Asymptotic Sig	*Mann-Whitney U.*	Mean (SD)	Skewness	Kurtosis	Asymptotic Sig	*Mann-Whitney U.*	Mean (SD)	Skewness	Kurtosis	Asymptotic Sig	*Mann-Whitney U.*
Gender																
Female	11	47.273 (14.079)	0.06	-1.861			78.091 (10.005)	0.12	0.136			40.182 (9.806)	0.723	-0.126		
Male	21	59.429 (10.385)	-0.434	-0.502	0.021	173.5	76.571 (10.792)	-0.461	-0.781	0.874	111.5	39.524 (11.102)	-0.327	0.244	0.952	114
Age (y)																
40-49	20	55.000 (13.294)	-0.62	-0.439			77.350 (11.450)	-0.364	-0.501			41.500 (9.517)	0.012	-0.281		
50-59	12	55.667 (12.950)	-0.339	-1.247	0.861	124.5	76.667 (8.804)	-0.258	-1.396	0.755	112	36.833 (11.854)	0.102	0.771	0.205	87.5
Educational Background																
Bachelor and below	21	59.500 (9.793)	-2.194	4.995			80.667 (9.070)	-1.066	1.096	0.874		40.333 (6.154)	0.292	-2.014		
Postgraduate	11	54.269 (13.555)	-0.314	-0.876	0.371	138	76.269 (10.660)	-0.184	-0.544		111.5	39.615 (11.381)	-0.065	-0.196	0.634	127.5
Household Income																
<$8000	17	53.118 (14.137)	-0.503	-1.397			78.882 (9.797)	-0.111	-0.718			39.647 (9.830)	-0.923	1.533		
≥8000	15	57.667 (11.475)	-0.258	-0.059	0.484	146	75.067 (11.003)	-0.407	-0.722	0.374	104	39.867 (11.600)	0.489	-0.582	0.664	116
Interaction with engineers																
Yes	14	62.857 (11.279)	-2.335	7.829			80.929 (10.824)	-0.774	-0.079			45.214 (9.916)	-0.095	-0.627		
No	18	49.333 (11.146)	0.133	-1.294	0.003	47.5	74.111 (9.260)	-0.334	-0.195	0.055	75.5	35.500 (9.102)	-0.51	0.499	0.016	62.5

Discussion

1. Singapore parents have little knowledge of engineering

On the construct of knowledge, Singaporean parents fared rather poorly. The results of our survey do not deviate greatly from the original survey conducted by Yun et al. (2010). Parents possess little knowledge of engineering and little awareness of engineering within the Singapore primary and secondary school curriculum. This is expected as engineering is taught implicitly, instead of explicitly, in the subjects of science and mathematics in Singapore schools. Additionally, the majority of survey participants reported having little interaction with engineers. Parents who reported little interaction with engineers had lower aggregated scores on the construct of knowledge (M=49.333, SD=11.146), compared to parents who reported they had greater interaction with engineers (M=62.857, SD=11.279). This finding supports an expert opinion that Singapore parents do not interact with those from STEM fields, causing them to "not fully understand what engineers do" (Shabana, 2019).

2. Singaporean parents have positive attitudes toward engineering

Singaporean parents are generally supportive of and have overall positive attitudes toward engineering in Singapore. As shown in Table 2, across the variables of gender, age, educational background, household income, and interaction with engineers, Singaporean parents had high scores for the Attitude construct. Engineering remains a significant industry in Singapore and an important facet of Singapore's economy. With the recent outbreak of the COVID-19 pandemic, there has been renewed interest in support within the STEM fields in Singapore (3M, 2021). In 3M's State of Science Index Survey (2019), 81% of Singaporeans expressed that they would encourage their children to enter the STEM fields, regardless of the gender of the child. This supportive attitude is concordant with international calls for more support for women in STEM-related fields (e.g., Yun et al., 2010; 3M, 2021).

3. Lack of behaviors to support engineering from parents

While Singaporean parents are generally very supportive of engineering, as seen by their positive attitudes, they do not participate in many activities that support engineering behaviors. As seen in Table 2, Singaporean parents had the lowest aggregated scores for the behavior construct compared to the other constructs of knowledge and attitude, and this was consistent across the variables of gender, age, educational background, household income, and interaction with engineers. A possible explanation for this is the lack of available programs that promote engineering behaviors, such as engineering fairs and locally-produced engineering-related science TV shows. The Singapore Science and Engineering Fair (SSEF) was only incepted in 2001 and its existence is still not well-known outside of the scientific circles within the Ministry of Education. Additionally, Singaporeans' options for engineering-related science programs are limited to overseas-produced TV shows that are available on pay-to-view channels. Moreover, Singaporean parents may spend less time engaging in such activities due to the demand of the long working hours in Singapore (Kisi, 2019). Thus, Singaporean parents may not engage frequently enough in activities to increase and support their children's interest in science and engineering.

Conclusion

There are current efforts by various educational institutes in Singapore to introduce and develop engineering skills to students at the K-12 level. However, these efforts are often targeted at the school and student level, and there is still room to expand efforts and policies to another important stakeholder in education—parents.

This study aims to encourage Singapore's Ministry of Education and other educational institutions to increase the visibility of engineering to parents, which may eventually encourage more students to pursue engineering. Parents play an important role in influencing children in their career paths. Increasing parents' knowledge of engineering and frequency of engineering behaviors to support the existing positive attitudes parents have towards engineering may encourage more students to be interested in engineering and eventually pursue it.

To promote engineering, the positive attitudes of parents can be leveraged, and more programs for parents to increase their knowledge of engineering and support their children's engineering education can be offered. One such program is the Applied Learning Programme (ALP). The ALP in STEM-related fields is offered in 60% of schools in Singapore. Parents can be incorporated into these programs, providing parents opportunities to discover engineering either alongside or in a similar manner to their children. Additionally, schools could inform parents of how engineering concepts and indices are already present across the pre-college physics curriculum (Yeter et al., 2022), through briefings and information materials, such as brochures or emails. This would also increase parents' knowledge of engineering within Singapore's school curriculum. The Ministry of Education may also consider collaborating with the state-owned media in order to increase the visibility of engineering by producing TV programs that can further develop an interest in science and engineering in Singapore.

This study offers insight into key areas that can be addressed to increase engineering awareness amongst Singapore parents by identifying key areas that are lacking. This study also provides a basis of comparison for future studies on engineering awareness in Singapore parents by setting the precedent of using the PEAS to understand parents' engineering awareness in Singapore. Future research could involve workshops that investigate how engineering behaviors that take place at home increase interest and the development of engineering skills in children.

References

3M. (2019). *State of science index.* https://www.3m.com.sg/3M/en_SG/state-of-science-index-survey-sg/2019-summary/

3M. (2021). *State of science index*. https://www.3m.com.sg/3M/en_SG/state-of-science-index-survey-sg/

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling practice: A review and recommended two-step approach. *Psychological Bulletin, 103*(3), 411-423.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*, 179-211.

Belfiore, P. J., & Hornyak, R. S. (1998). Operant theory and application to self-monitoring in adolescents. In D.H. Schunk & B. J. Zimmerman, (Eds.) *Self-regulated learning: From teaching to self-reflective practice* (pp. 184-202). New York: The Guilford Press.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, O. R. (1956). *Taxonomy of educational objectives: The classification of educational goals.* New York, NY: Longman.

Bloom, B. S. (1976). *Human characteristics and school learning*. New York: McGraw-Hill.

Burley, H., Williams, C. M., Youngblood, T. D., & Yeter, I. H. (2016, June), Understanding "failure" is an Option. In *Proceedings of American Society for Engineering Education (ASEE) Conference & Exposition,* New Orleans, Louisiana. 10.18260/p.27095

Burley, H., Youngblood, T. D., Yeter, I. H., & Williams, C. M. (2016, June). Engineering an evaluation for a growing rocket program: Lessons learned. In *Proceedings of American Society for Engineering Education (ASEE) Conference & Exposition,* New Orleans, Louisiana. 10.18260/p.26616

Youngblood, T. D., Yeter, I. H., Williams, C. M., & Burley, H. (2016, June), STEMChoice: An examination of program evaluation data in a STEM-centered, inquiry-based program. In *Proceedings of American Society for Engineering Education (ASEE) Conference & Exposition,* New Orleans, Louisiana. 10.18260/p.25875

Dorie, B. L., Jones, T. R., Pollock, M. C., & Cardella, M. (2014, June 15-18). *Parents as critical influence: Insights from five different studies* [Paper Presentation]. 121st ASEE Annual Conference & Exposition, Indianapolis, Indiana. http://docs.lib.purdue.edu/enegs/55

Fabrigar, L. R., Petty, R. E., Smith, S. M., & Crites, S. L. (2006). Understanding knowledge effects on attitude-behavior consistency: The role of relevance, complexity, and amount of knowledge. *Journal of Personality and Social Psychology, 90*(4), 556–577. https://doi.org/10.1037/0022-3514.90.4.556

Gagne, E. D., Yekovich, C. W., & Yekovich, F. R. (1993) *The cognitive psychology of school learning* (2nd ed.). New York: HarperCollins.

Gauvain, M. (2001). *The social context of cognitive development.* New York: Guildford Press.

Glenzer, H. (2005). Living learning theory through My Fair Lady. *British Journal of Educational Technology, 36*(1), 101–105. https://doi.org/10.1111/j.1467-8535.2004.00443.x

Kisi. (2019). *2019 work-life balance index.* https://www.getkisi.com/work-life-balance#table

Lim, T. M. (July 16, 2019). Singapore must guard against a dearth of engineering talent. *TodayOnline*. https://www.todayonline.com/commentary/singapore-must-guard-against-dearth-engineering-talent

Liu, L., Liu, Y. P., Wang, J., An, L. W., & Jiao, J. M. (2016). Use of a knowledge-attitude-behaviour education programme for Chinese adults undergoing

maintenance haemodialysis: Randomized controlled trial. *The Journal of International Medical Research. 44*(3), 557–568. https://doi.org/10.1177/0300060515604980
Miller, T. E., Booraem, C., Flowers, J. V., & Iversen, A. E. (1990). Changes in knowledge, attitudes, and behavior as a result of a community-based AIDS prevention program. *AIDS education and prevention : official publication of the International Society for AIDS Education, 2*(1), 12–23.
Ministry of Education. (2018, August 6). *Course choice for top-performing students*. https://www.moe.gov.sg/news/parliamentary-replies/20180806-course-choice-for-top-performing-students
Monk's Hill Ventures, & Glints. (2021). *The Southeast Asia tech talent compensation report.* https://www.monkshill.com/content-hub/the-southeast-asia-tech-talent-report-mhv
Schrader, P. G., & Lawless, K. A. (2004). The knowledge, attitudes, & behaviors approach how to evaluate performance and learning in complex environments. *Performance Improvement (International Society for Performance Improvement), 43*(9), 8–15. https://doi.org/10.1002/pfi.4140430905
Singapore Department of Statistics. (2020) *Key Household Income Trends*. SingStat. https://www.singstat.gov.sg/-/media/files/publications/households/pp-s26.pdf
Schwiderski, A. (2018). *A comparison of first-year persistence in first-generation and non-first-generation college students: A multiple regression study* [Doctoral dissertation, Saint Louis University]. ProQuest Dissertations Publishing.
Shabana, B. (2019). Fewer Singaporeans are choosing careers in science, technology, engineering and mathematics: Survey. *The Straits Times*. https://www.straitstimes.com/singapore/fewer-singaporeans-are-choosing-careers-in-stem-survey
Skinner, B. F. (1953). *Science and human behavior*. New York: Macmillan.
Steup, M., & Neta, R. (2020). Epistemology. *Opgehaal van The Stanford Encyclopedia of Philosophy.* https://plato.stanford.edu/archives/fall2020/entries/epistemology/
Sutinen, A. (2007). Constructivism and education: education as an interpretative transformational process. *Studies in Philosophy and Education, 27*(1), 1–14. https://doi.org/10.1007/s11217-007-9043-5
Tan, I. G. (1996). *A study of environmental knowledge, attitudes and behaviour of junior college and secondary students in Singapore* [Unpublished master's thesis]. National Institute of Education, Nanyang Technological University.
Tan, O. S., Chye, Y. L. S., Lim, K. J., Chua, B. L., Tuckman, B. W., Monetti, D. M. (2017). *Educational psychology: An Asia edition*. Singapore: Cengage Learning.
Tan, S. C. (March 04, 2021). Why Singapore needs engineering talents more than ever. *TodayOnline.* https://www.todayonline.com/voices/why-singapore-needs-engineering-talents-more-ever
Venkatesh, S., Yeter, I.H., & Fong, E. (2022). An initial investigation of funds of knowledge for first-generation and continuing-generation engineering students in Singapore. In *Proceedings of American Society for Engineering Education (ASEE) Conference & Exposition,* Minnesota, MN.
Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Trans.). Cambridge, MA: Harvard University Press.

Yeter, I.H., Radloff, J., & Diordieva, C. (2022). Exploring the presence of engineering indices in the Singaporean high school physics standards: A content analysis (work-in-progress). In *Proceedings of American Society for Engineering Education (ASEE) Conference & Exposition*, Minnesota, MN.

Yeter, I. H., & Burley, H., & Youngblood, T. D., & Williams, C. M. (2016, June), Developing a questionnaire and evaluation methods for a high school rocket program. In *Proceedings of American Society for Engineering Education (ASEE) Conference & Exposition,* New Orleans, Louisiana. 10.18260/p.26730

Yun, J., & Cardella, M., & Purzer, S., & Hsu, M., & Chae, Y. (2010, June). *Development of the Parents' Engineering Awareness Survey (Peas) according to the knowledge, attitudes, and behavior framework* [Paper Presentation]. 2010 Annual Conference & Exposition, Louisville, Kentucky. 10.18260/1-2--16293