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Person-centered analysis of factors related to STEM students' global awareness

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Abstract

Background: Twenty-first century communication has changed how we connect to the rest of the world. Therefore, it requires the preparation of undergraduate science, technology, engineering, and mathematics (STEM) students who are capable of coping with problems on a global scale and who can participate effectively in a global economic and civic environment. Breathtaking ability to send vast amounts of data instantly and at times globally often translates to graduates entering the workforce needing to be aware of the global community. Hence, in this study, factors related to engineering students' global awareness have been explored so that higher education institutions may consider those factors when designing programs meant to influence this competence. The current study used a validated new instrument, based on a developmental model—the Model of Domain Learning (MDL)—to gauge engineering students' growth in global awareness. The presented research is studying the following research question: *What is the relation between students' curricular and co-curricular experiences and levels of global awareness classified using MDL?*

Results: Person-centered analyses were used to answer the research question. Four hundred twenty-five engineering students, who enrolled in 18 different engineering programs in a US land-grant university, participated in this study. The study found that engineering students' engagement in extra-curricular activities was correlated with an increase of their knowledge, strategic processing, and interest in the domain of global awareness.

Conclusions: Based on the data analysis, students' international experiences were positively related to not only their interest and knowledge but also their strategic processing predicted by the MDL. Moreover, engineering students' international experience and high academic engagement are important variables related to their perception of increased global awareness and improved skills for international careers. Hence, higher education institutions should consider making pedagogical interventions in their programs to effectively embed international experience into students' curriculum.

Keywords: Twenty-first century skills, Assessment, Globalization, Factors, STEM education, Undergraduate, Interest, Knowledge, Strategic processing, Mixed-methods

Background

Global awareness

The importance of arming students with twenty-first century skills has recently been emphasized (Stehle & Peters-Burton, 2019). Engaging students with cultures other than their own promotes collaborative problem-solving skills and encourages students to formulate problems differently and to devise solutions considering important human dimensions (Downey et al., 2006; Zou & Mickleborough, 2015). Global competency, which is a complex and multi-dimensional construct, is defined as a set of knowledge and skills to understand the world, comprehend current global problems and affairs, and devise solutions considering human dimensions as well as a positive attitude towards interacting peacefully, respectfully, and productively with people from diverse cultures (Reimers, 2009, 2010). A globally competent

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person is the one with enough substantive knowledge, perceptual understanding, and intercultural communication skills to effectively interact in our globally interdependent world (Olson & Kroeger, 2001). The traits of a globally competent employee include (*i*) an awareness of the wider world and a sense of the role as a world citizen; (*ii*) an understanding of how the world works economically, politically, socially, culturally, technologically, and environmentally; (*iii*) an outrage of social injustice; (*iv*) a commitment to participate in and contribute to the community at a range of levels from local to global; (*v*) a willingness to act to make the world a more sustainable place; and (*vi*) acceptance of responsibility for individual actions (Fawson & Naffziger, 2012). Rationales for educating globally competent students involves (*i*) changing demands of work due to the flattened global economy; (*ii*) developing multi-cultural tolerance and understanding due to the increased level of immigration; and (*iii*) addressing climate instability and environmental problems (Mansilla & Jackson, 2011). Similarly, it has been suggested that education should help students to develop global perspectives and cross-cultural awareness (Hanvey, 1976).

Intercultural competence, referring to people's capability for engaging in appropriate and effective intercultural interactions, can be learned and developed (Guo, 2019), and it should be considered as an important learning outcome of internationalizing institutions (Huang, 2017). Global awareness is a precursor to global competency. According to the definitions of global awareness given by Merryfield (1997) and Hanvey (1976), the domain of global awareness includes the set of concepts and issues shaping our world as follows: (*i*) world history and politics, (*ii*) knowledge about other cultures, (*iii*) environmental issues, (*iv*) socio-economic and political systems, and (*v*) global events. The definitions of global awareness also align with a specific learning outcome (3h) of the Accreditation Board for Engineering and Technology (ABET), Inc.: "understand the impact of engineering solutions in a global, economic, environmental, and societal context" (Pascow & Pascow, 2017, p. 481). Hence, we adopted this learning outcome in our study and defined a globally aware student as *a student who understands the impact of engineering solutions in a global, economic, environmental, and societal context*.

Awareness outcomes are difficult to measure in technical fields where awareness should be incorporated into problem-solving activities in a global and social context (Shuman et al., 2005). Lohmann et al.'s (2006) conceptual model for defining global competence, which is based on proficiency in a second language, international coursework, and immersive international experiences, suggested that these mentioned elements should be combined in a coherent program integrating them within a student's major. It is important to identify, develop, and provide opportunities for international collaboration in order to develop global competence as an important learning outcome for engineering graduates (Warnick, 2011). Global engineering competency (GEC) framework developed by Jesiek et al. (2014) and further analyzed by Mazzurco et al. (2020) consisted of three main contextual dimensions of global engineering competency: (*i*) technical coordination, (*ii*) engineering cultures, and (*iii*) ethics, standards, and regulations.

In this study herein, person-centered analyses were used for gaining an understanding of the background and demographical factors related to students' global awareness. The current study was built upon an earlier work by Kulturel-Konak et al. (2019) who proposed and validated an instrument based on the Model of Domain Learning (MDL) (Alexander et al., 1997; Alexander, 2003) to measure students' development in global awareness in three dimensions: knowledge, strategic processing, and interest. Person-centered analyses were used to study the differences between the backgrounds and educational experiences of students with high and low global awareness levels and to investigate whether any observed patterns in such differences support the MDL-based framework to assess global awareness.

Model of Domain Learning (MDL) framework

The changes and interplay among knowledge, strategic processing, and interest can be used to evaluate engineering students' global awareness development utilizing the Model of Domain Learning (MDL) framework (Kulturel-Konak et al., 2019). The MDL gauges students' growth in a particular area through stages in three components: knowledge, strategic processing, and interest. The framework entails experience-based stages and learning-based components (Alexander et al., 1997; Kulturel-Konak et al., 2015).

The experience-based stages of the MDL are *acclimation*, *competency*, and *proficiency*. In the acclimation stage, the field of study is new and challenging for the student. Next, the student transitions to the competency stage, which involves increased cohesion, improved problem-solving skills, and more personal connections. Students in the proficiency stage contribute as experts to the field of study with continuous engagement, investigations, and making connections among the learning-based components (Alexander, 2003).

The learning components of the MDL are *knowledge*, *strategic processing*, and *interest*. Table 1 summarizes the definition of the experience-based stages of the MDL and how the learning components, knowledge, strategic processing, and interest, change through these three stages using global poverty as an example. In terms of knowledge, students are getting better at making

Table 1 Description and examples of the MDL components and stages

	Acclimation	Competency	Proficiency
Knowledge	Limited and fragmented knowledge. Example: Basic awareness of poverty as an important global problem.	More cohesive domain knowledge principled in structure. Example: Knowledge about poverty in different regions of the Word.	Broad and deep knowledge. Example: Knowledge and understanding about the factors leading to poverty in different regions of the Word.
Strategic processing	Surface-level strategies: The implicit acceptance of information and memorization as isolated and unlinked facts. Example: Fact-finding in a text or Internet about poverty.	A mixture of surface-level and deep processing strategies. Example: Perform a web search to see a particular solution is applied in a current situation.	Deep processing strategies: Critically evaluate the problem, given facts, and alternatives. Example: Analyze a dilemma about poverty from different cultural or economic perspectives.
Interest	Situational interest: Spontaneous, transitory, and environmentally activated interest that is associated with increased attention when a new topic is introduced. Example: Read an online article about poverty as a part of a class assignment.	Increased individual interest due to increased engagement in a domain. Example: Perform a web search to learn more about poverty.	Individual interest: Long-term, deepening, personal connection to a domain, which in turn inspires further exploration of the domain. Example: Voluntarily attend a seminar or workshop about poverty.

connections among topics learned as they improve throughout their educational journey. The acclimation stage entails knowledge being limited and fragmented. Then, in the competency stage, the knowledge is more cohesive and principled in structure. In the proficiency stage, the knowledge is broad and deep in certain topics.

Strategic processing considers problem-solving strategies. In the acclimation stage, students only use surface-level strategies, which means that the memorization and facts are unlinked and isolated. New concepts are learned by memorizing facts. The competency stage entails students using a combination of surface-level strategies and deep processing strategies. The deep processing strategies are defined as the use of problem-solving procedures to integrate knowledge. In the proficiency stage, students only apply deep processing strategies.

When transitioning through the experience-based stages, interest shifts from situational interest to individual interest. First, situational interest involves students being intrigued due to new stimuli in the specific topic and occurs in the acclimation stage. In the competency stage, there is an increased engagement which leads to students becoming more interested in the specific topic. Lastly, individual interest refers to a students' personal, long-lasting and deepened connection to the topic studied, and an indicator of individual interest is further research into the domain. Studying the validity of the MDL, Kulturel-Konak et al. (2019) showed that the predictions of the MDL are valid in the domain of global awareness nested within engineering programs.

Global awareness assessment tools

There are several instruments in the literature to evaluate students' global awareness. However, these instruments do not address all components of the MDL. In Table 2, we summarize the existing global awareness instruments based on how these instruments relate to the knowledge, strategic processing, and interest components of the MDL. As seen in Table 2, although there are a number of general assessment tools to measure global awareness of students, only a limited number of

Table 2 Previous assessments for global awareness

Assessment area	Assessment tools
General	Developmental Model of Intercultural Sensitivity (DMIS) (Bennett, 1986) Cross-Cultural Sensitivity Scale (CCSS) (Pruegger & Rogers, 1993) Cultural Intelligence Scale (CQ) (Ang, Van Dyne, & Koh, 2006) Revised Intercultural Development Inventory (IDI) (Hammer et al., 2003) Miami University Diversity Scale (MUDAS) (Mosely-Howard et al., 2011) Global Perspective Inventory (GPI) (Braskamp et al., 2014)
Knowledge	The Ohio State Global Awareness Test (Woyach, 1988) Global Awareness Profile (GAP) (Corbitt, 1998)
Strategic processing	Cross-Cultural Adaptability Inventory (CCAI) (Kelley & Meyers, 1987) Multicultural Personality Questionnaire (MPQ) (van der Zee & van Oudenhoven, 2000) Wesleyan Intercultural Competence Scale (WCIS) (Stemler et al., 2014)
Interest	Interest in Foreign Language Scale (Kim & Goldstein, 2005) Miville-Guzman Universality-Diversity Scale— Short form (MGUDS-S) (Jesiek et al., 2012)

those tools are targeting to assess global awareness aligning with the MDL components. Hence, in this study, factors related to engineering students' global awareness have been explored so that higher education institutions may consider those factors when designing those programs meant to influence this competence. In addition, when administered in particular classes, instructors might choose to provide survey participants with formative feedback. The current study used a validated new instrument, based on a developmental model—the Model of Domain Learning (MDL)—to gauge engineering students' growth in global awareness. Interested readers may also further refer to Fantini (2009), Deardorff (2009), Deardoff (2015), Matsumoto and Hwang (2013), and Matveev (2017) for the reviews of assessment and survey tools in the area of intercultural competence and related constructs.

Factors related to students' global awareness

Similar to our main research focus, several researchers have studied the factors related to students' global awareness. In Clarke's (2004) study, global awareness was measured by the following: (*i*) academic study of at least a year of a foreign language, (*ii*) number of visits to a foreign country, (*iii*) degree of exposure to the media through television, magazines, and journals, (*iv*) study of a course in non-western civilization, and (*v*) personal involvement (the number of times the respondent had visited or entertained someone from another country). The regression analysis shows that the study of a course or a foreign language and international travels made positive contributions to the attitudes of internationalism.

Similarly, it was stated that out of the comfort zone experiences through international mobility contribute to students' process of becoming global citizens (Killick, 2012). Another study concluded that the factors contributing to students' global perspectives are their curricular and co-curricular activities, but not related to most social location and academic factors, such as parents' education and GPA, and interestingly, students' global perspectives were found not to be related to their study abroad participation (Ferguson, 2013). It was suggested that study abroad programs could be very salient in developing students' intercultural wonderment as long as faculty and staff organizing those programs are very careful in setting program outcomes and fostering cultural exposures opportunities (Engberg et al., 2016). Similarly, participation in study abroad, service-learning, engineering courses with a global focus, and personal tourism abroad were positively associated with students' engineering global preparedness (Levonisova et al., 2015). Lokkesmoe et al.'s (2016) findings supported that exposure alone is not sufficient to affect intercultural competence at cognitive, metacognitive, motivational, and behavioral levels. Green (2019) proposed a framework of students as partners (SaP), an Australian Learning and Teaching Fellowship bringing students and academics together from diverse disciplinary, cultural, and national backgrounds to co-develop rich global learning experiences and showed that adopting a partnership approach enabled all participants to engage in global learning.

Although it was suggested in the literature that students' involvement in curricular and co-curricular experiences contributes to building their global awareness, the literature still needs a study analyzing the degree of this relation and while doing this, it is better to use an assessment framework, such as MDL. Hence, in this study, the following research question is explored:

RQ: What is the relation between students' curricular and co-curricular experiences and levels of global awareness classified using MDL?

Methods

Participants and data collection

The target population in this study included all students majoring in engineering and engineering technology programs at the university. Participation in the study was voluntary without any incentives. The response rate was about 25%.

The cleaned data set (after dropping participants with (*i*) suspicious/unusual response patterns and (*ii*) any incomplete survey responses, i.e., missing items) included 425 undergraduate students (78.35% male and 21.64% female) from 18 different engineering and engineering technology programs at a land-grant university in the Northeast United States. Of these students, 36% of participants were first-year students, 28.70% were second-year, 21.64% were third-year, and 13.64% were fourth-year. For the purpose of analysis, first-year and second-year students were considered as lowerclassmen and third-year and fourth-year students as upperclassmen. Participants were from Mechanical Engineering (19.06%), Industrial Engineering (13.88%), Computer Science and Engineering (9.18%), Engineering Technology (9.18%), Chemical Engineering (7.53%), Civil Engineering (6.82%), Surveying Engineering (5.88%), Electrical Engineering (5.65%), Aerospace Engineering (5.18%), Biomedical Engineering (3.76%), Architectural Engineering (3.53%), and other engineering programs (10.35%).

The data set used in this study was previously collected in an empirical study using the instrument developed and validated by Kulturel-Konak et al. (2019) to investigate the applicability of an MDL-based approach for assessing global awareness. The survey was distributed via emails including an anonymous link of the instrument URL.

Instrument—content validation and internal consistency

Figure 1 shows the rigorous process to establish the content validation and internal consistency of the instrument which was used by Kulturel-Konak et al. (2019). Following the MDL framework, the instrument has three dimensions: knowledge, strategic processing, and interest. The knowledge and strategic processing variables are measured by multiple-choice test questions while the interest variables are measured by continuous Likert-scaled self-reporting questions. The details of the knowledge and strategic processing tests can be found in Kulturel-Konak et al. (2019). The measurement models and items for the interest variables were validated for the subgroups of the students based on their academic standing (Kulturel-Konak et al., 2019). In the current study, the interest variables were measured for the whole dataset. Therefore, the interest measurement model was tested using confirmatory factor analysis to ensure that the dataset fit the previous measurement model.

Knowledge

The global awareness knowledge of students was measured by a test of 28 multiple-choice questions about different topics, such as global customs and culture, global events, geography, economy, religion, food, language, history, and political/economic issues. These multiple-choice knowledge questions were also developed by Kulturel-Konak et al. (2019) based on literature review and content validated by a panel of subject matter experts, including academicians and industry practitioners. Further, a group of undergraduate students reviewed the questions to ensure that the questions were relevant to undergraduate students. The questions were categorized into three levels as acclimation (eight), competency (ten), and proficiency (ten) representing the developmental stages of the MDL based on their difficulty. The percentage of the correct answers by each student was used as the score of the student's global awareness knowledge. The overall knowledge test had a difficulty index of 0.64, Kuder-Richardson Formula 20 (KR-20) reliability of 0.81, and the average discrimination index of 0.41.

Strategic processing

The strategic processing variable was measured by ten short case-study questions that assessed students' ability to apply global awareness knowledge to critically evaluate problems, given facts, and solution alternatives. Each case-study question introduced a problem related to global issues, and students were expected to select the best course of action among the four choices marked as the most appropriate choice (scored as 5), the distractor choice (scored as 3), and two incorrect choices (scored as 1). In other words, the short-case studies were scored polytomously, and the strategic processing score for each student was calculated as the percentage of the total score of the student out of the maximum possible score. The ten strategic-processing questions were grouped into three levels: acclimation (three), competency (three), and proficiency (four). These questions were crafted with the help of a panel of undergraduate students who provided feedback to the extent that the questions represent real-world scenarios faced by undergraduate students and their expected behaviors (Kulturel-Konak et al., 2019). Overall, the strategic processing test had the KR-20 reliability of 0.67, the average discrimination index of 0.40, the minimum discrimination index of 0.24, and the average difficulty index of 0.69.

Interest

According to the MDL, an important indicator of professional development in a domain is demonstrating individual interest. The interest dimension of the instrument includes two constructs: (*i*) engagement interest

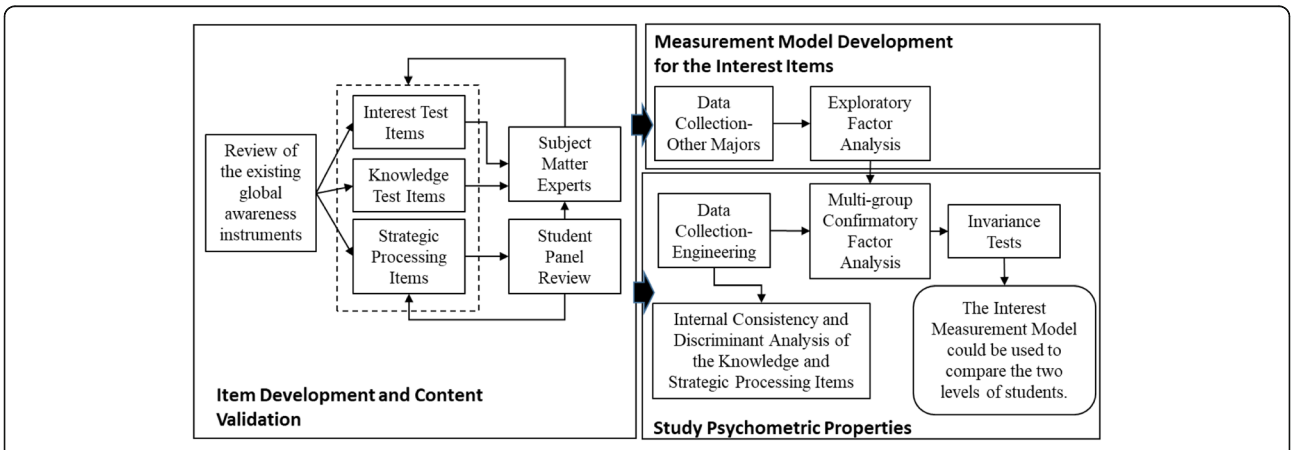

Fig. 1 The research process of the instrument development and validation

and (*ii*) intentional interest. The engagement interest items measure how frequently students participated in activities related to global awareness in the last 2 years on a five-level rating scale (1 = none, 2 = once or twice, 3 = three or four times, 4 = five or six times, and 5 = more than six times). Based on the result of an exploratory factor analysis on a larger data set that included other majors, Kulturel-Konak et al. (2019) further defined two latent variables: (*i*) engagement interest-casual and (*ii*) engagement interest-deliberate. The main difference between these two latent variables is the effort that students put in to perform the activities described in the corresponding items. For example, "reading an online article about global issues" is considered as an engagement interest-casual, whereas "reading a book about global issues" is considered as an engagement interest-deliberate since the latter needs the student to get much more interested about the specific topic than the former. While undergraduate students are expected to perform the engagement interest-causal items easily, they need to put a more concerted effort into the engagement interest-deliberate items.

Data analysis

Confirmatory factor analysis

In the current study, a confirmatory factor analysis (CFA) was performed to test whether or not the data set fits the engagement interest measurement model of the instrument. Table 3 presents the engagement interest items and the standardized regression coefficients of the CFA. The average ratings of these items were used as the engagement interest scores.

The intentional interest construct represents students' intentions to take part in professional development activities. This construct was measured by sliding bar items with a scale from 0 (not interested at all) to 100 (very much interested). In the measurement of self-efficacy, continuous scales with a 0–100 response range were known to be psychometrically stronger and had a better discriminating power compared to traditional discrete rating scales with several options (Pajares et al., 2001; Bandura, 2006). The measurement model of the intentional interest construct has also two latent variables: (*i*) intentional interest-easy and (*ii*) intentional interest-effortful. The main difference between these two latent variables is the required effort for performing the activities given in the items. Similar to the analysis for the engagement interest measurement model of the instrument, the fit of the data set to the intentional interest measurement model was tested by a CFA. Table 4 presents the standardized regression coefficients of the intentional interest items. The average ratings of these items were used as the intentional interest scores. The items that loaded on the intentional interest-effortful latent variable require more effort to perform than the items loaded on the intentional interest-easy. For example, following current news about terrorism in the world today on your own is considered intentional interest-easy whereas willingness to take an elective course in order to improve one's global awareness is considered as intentional interest-effortful. In summary, the interest dimension of the instrument includes two constructs (each with two latent variables) as follows: (*i*) engagement interest (engagement interest-casual and engagement interest-deliberate) and (*ii*) intentional interest (intentional interest-easy and intentional interest-effortful).

Cluster analysis

We conducted a person-centered cluster analysis (Von Eye & Wiedermann, 2015; Howard & Hoffman, 2018) to gain an understanding of the background and demographical factors related to students' global awareness knowledge, strategic processing, and interest scores.

Table 3 CFA standardized regression coefficients for the engagement interest items ($p < 0.001$ for all items)

Latent variable	Items	Regression coefficients
Engagement interest-casual	Q3. Read an online article about global issues.	.74
	Q9. Performed a web search to learn about global awareness/issues.	.81
	Q5. Had a conversation with your friends about global issues.	.71
	Q4. Read a newspaper/magazine article about global issues.	.60
	Q6. Watched a video clip or foreign film outside of classwork about global awareness/issues.	.70
Engagement interest-deliberate	Q11. Attended a cultural dinner or event on campus.	.54
	Q12. Coordinated or taken part in a fundraiser for a global issue.	.59
	Q1. Attended a seminar or speaker event about global awareness/issues.	.72
	Q8. Asked questions to a professor about global awareness/issues.	.61
	Q2. Read a book about global awareness/issues.	.63

Table 4 Standardized regression coefficients (CFA) for the engagement interest items

Latent variable	Items	Regression coefficients
Intentional interest-effortful	Q19. Rate your level of interest in attending a free workshop on global awareness.	.840
	Q22. A renowned global awareness specialist will give a workshop on "issues with intercultural communication in multinational organization" at your institution. Rate your level of interest in attending this workshop.	.911
	Q20. Rate your level of willingness to take an elective course in order to improve your global awareness.	.724
	Q23. A cross-cultural dinner is being held on campus featuring food and music from different parts of the world, and it is free to attend. Rate your likelihood of attending the event.	.580
Intentional interest-easy	Q25. While you are browsing a news website, you have spotted an article entitled "Economic Problems in Europe." Rate your likelihood of reading this article.	.743
	Q26. How likely are you to follow, on your own, current news about terrorism in the world today?	.550
	Q21. Rate your level of interest in reading literature about global issues.	.834

$p < 0.001$ for all items

Person-centered analyses investigate how variables group within individuals. On the other hand, variable-centered analyses consider how characteristics are related to each other. Hence, the data speak to themselves by grouping individuals with similar patterns. The cluster analysis was used to answer our research question. Four variables, knowledge-proficiency, strategic processing-proficiency, engagement interest-deliberate, intentional interest-effortful, were used to form clusters using the two-step clustering algorithm (Bacher et al., 2004), which is known to be robust when the clustering variables have different scales. The two-step clustering algorithm can also automatically determine the best number of clusters and provides a validation criterion of consistency within clusters of data.

Logistic regression

As a final step in the analysis, we performed a logistic regression on the clustered data to determine whether these demographical/academic variables were statistically significant factors in determining the cluster membership of the participants and whether the presented ratios were statistically different across the clusters. A similar person-centered clustering approach followed by logistic regression was also used earlier in the engineering education literature (Knight, 2014).

Results

As given in Tables 3 and 4, all standardized regression coefficients of the interest construct latent variables exceeded 0.5 and were significant ($p < 0.001$) for both measurement models. Table 5 summarizes Cronbach's alpha (α), composite reliability (CR), average variance extracted (AVE), correlation coefficients between the latent variables, and the heterotrait-monotrait ratio (HTMT) of the correlations of the latent variables to gauge the internal consistency, convergent, and discriminant validity of the latent variables based on the CFA. The correlation coefficients between the latent variables of engagement interest were lower than 0.85, which is considered a threshold for supporting discriminant validity (Kline, 2015). The HTMT values, 0.488 and 0.314, were less than the threshold value of 0.85 (Henseler et al., 2015). Therefore, discriminant validity was supported for both latent variables of the engagement interest and intentional interest constructs.

The clustering algorithm was terminated after determining two clusters with silhouette cohesion and separation statistics of 0.40, which is considered as fair. As presented in Table 6, the means of the knowledge, strategic processing, and interest variables were quite different between the clusters. We compared the mean values of the variables across cluster I and cluster II using one-way ANOVA. The mean differences of all variables across the clusters were statistically significant ($p < 0.001$ for all variables), and the F values of the test are presented in Table 6. Table 7 presents the first (Q1), second (Q2-median), and third (Q3) quartiles of the variables across the identified clusters. Cluster I ($n = 236$),

Table 5 Internal consistency, convergent validity, and discriminant validity of the measurement models

Statistics	Measurement models			
	Engagement interest		Intentional interest	
	Causal	Deliberate	Easy	Effortful
α	0.838	0.759	0.763	0.843
AVE	0.519	0.393	0.516	0.599
CR	0.842	0.762	0.757	0.853
Cor. coeff.	0.544		0.800	
HTMT	0.488		0.314	
χ^2	125.49		47.538	
df	34		13	
CFI	0.935		0.975	
RMSEA	0.080		0.079	

Table 6 Means and standard deviations for knowledge, strategic processing, and interest for the low and high global awareness clusters

		All groups (n = 425)	Cluster I Low global awareness (n = 236)	Cluster II High global awareness (n = 189)	F values of ANOVA
		M (SD)	M (SD)	M (SD)	
Knowledge	Acclimation	90.56 (14.82)	87.66 (16.33)	94.18 (11.76)	21.25*
	Competency	70.02 (22.91)	64.70 (24.83)	76.66 (18.24)	30.62*
	Proficiency	36.45 (22.58)	25.84 (16.57)	49.68 (22.11)	161.14*
Strategic processing	Acclimation	80.44 (19.79)	76.18 (20.77)	85.75 (17.12)	44.10*
	Competency	73.11 (18.54)	68.53 (19.79)	78.83 (15.04)	12.68*
	Proficiency	56.47 (16.72)	48.87 (13.42)	65.96 (15.57)	100.97*
Engagement interest	Casual	3.43 (1.09)	3.01 (1.07)	3.95 (0.87)	92.72*
	Deliberate	1.74 (0.74)	1.33 (0.34)	2.23 (0.80)	238.50*
Intentional interest	Easy	55.24 (24.36)	44.24 (24.04)	68.96 (16.57)	144.73*
	Effortful	44.38 (25.53)	31.49 (20.88)	60.47 (20.55)	204.90*

M mean, *SD* standard deviation
*The difference between the means of cluster I and cluster II is statistically significant at $p < 0.001$

which we will refer to as the low global awareness cluster, performed consistently lower on all levels of knowledge, strategic processing, and interest measures. In contrast, cluster II (n = 189), which we will refer to as the high global awareness cluster, had consistently higher scores for all variables. As presented in Table 7, the variables used for the two-step clustering, namely, knowledge-proficiency, strategic processing-proficiency, engagement interest-deliberate, and intentional interest-effortful, are particularly different between the clusters, and they are also symmetric around their medians (Q2) compared to the other variables.

Table 8 presents the demographical and academic background variables of the participants and the number of participants classified into the low or high global awareness clusters in each demographical/academic category with two levels. Although some of the categories listed in Table 8 had a limited number of participants (e.g., study abroad or volunteered overseas), a profile of the participants in the high global awareness cluster emerged. Most notably, a high percentage of international students (n = 36 out of 43, 83.72%) fell into the high global awareness cluster. Similarly, a large percentage of students participating in the study abroad programs (n = 25 out of 33, 75.76%) or volunteering overseas as part of an international organization/mission trips (n = 20 out of 27, 74.07%) fell into the high global awareness cluster. Given the apparent association among these three characteristics, we created a new composite category called international experience (n = 91) that included all students in these three categories. As seen in

Table 7 First quartile (Q1), median (Q2), and third quartile (Q3) for knowledge, strategic processing, and interest for the low and high global awareness clusters

Variable		Cluster I Low global awareness (n = 236)			Cluster II High global awareness (n = 189)		
		Q1	Q2	Q3	Q1	Q2	Q3
Knowledge	Acclimation	77.78	88.89	100.00	88.89	100.00	100.00
	Competency	50.00	70.00	80.00	60.00	80.00	90.00
	Proficiency	10.00	20.00	40.00	30.00	50.00	70.00
Strategic processing	Acclimation	60.00	80.00	90.00	80.00	90.00	100.00
	Competency	60.00	73.33	86.67	73.33	73.33	86.67
	Proficiency	46.67	60.00	73.33	60.00	73.33	86.67
Engagement interest	Casual	2.20	2.80	3.80	3.40	4.20	4.60
	Deliberate	1.00	1.20	1.60	1.60	2.00	2.80
Intentional interest	Easy	26.00	44.67	63.33	58.67	70.00	80.00
	Effortful	13.75	29.50	47.00	48.00	62.00	73.50

Table 8 Demographic and academic characteristics of students classified as low (cluster I) or high (cluster II) global awareness

Variable	Level	Number of participants	Low global awareness (cluster I) (%)	High global awareness (cluster II) (%)
Class standing	Under	275	62.55	37.45
	Upper	150	42.67	57.33
Gender	Male	333	59.46	40.54
	Female	92	41.30	58.70
Dean's list	No	245	56.73	43.27
	Yes	180	53.89	46.11
Part-time job	No	250	50.40	49.60
	Yes	175	62.86	37.14
Professional society member	No	350	58.00	42.00
	Yes	75	44.00	56.00
Honor student	No	359	56.82	43.18
	Yes	66	48.48	51.52
International student	No	382	59.95	40.05
	Yes	43	16.28	83.72
Student organization member	No	218	63.76	36.24
	Yes	207	46.86	53.14
Full-time job	No	396	54.80	45.20
	Yes	29	65.52	34.48
Enrolled in minor	No	343	59.18	40.82
	Yes	82	40.24	59.76
Double major	No	404	56.44	43.56
	Yes	21	38.10	61.90
Undergraduate research	No	364	59.07	40.93
	Yes	61	34.43	65.57
Club/varsity sports	No	356	56.74	43.26
	Yes	69	49.28	50.72
Study abroad	No	392	58.16	41.84
	Yes	33	24.24	75.76
Volunteered overseas	No	398	57.54	42.46
	Yes	27	25.93	74.07

Table 9, 76.92% of the students in this composite category were in the high global awareness cluster.

After international experience, the secondary influential demographical/academic variables were related to academics such as double major (61.9% in cluster II), enrolled in a minor (59.76% in cluster II), and participating in undergraduate research (65.57% in cluster II). We combined these categories into a new composite category called high academic engagement (n = 131). Among participants in the high academic engagement category, 59.09% of the students were in cluster II. In addition, the majority (58.70%) of female participants (n = 92) were also in cluster II. The majority (62.86%) of participants who indicated having a part-time job (n =

Table 9 Composite characteristics of students classified as low (cluster I) or high (cluster II) global awareness

Variable	Level	Number of participants	Low global awareness (cluster I) (%)	High global awareness (cluster II) (%)
International experience	No	334	64.37	35.63
	Yes	91	23.08	76.92
High academic engagement	Low	293	62.12	37.88
	High	132	40.91	59.09

175) were in cluster I. In addition, the majority (62.55%) of underclassmen (first-year and second-year) participants were in cluster I.

As mentioned earlier, a logistic regression on the clustered data was performed as the final step of our analysis to determine whether these demographical/academic variables were statistically significant factors in determining the cluster membership of the participants and whether the presented ratios were statistically different across the clusters. In the logistic regression, the independent variables included composite categories of international experience and high academic engagement along with class standing, gender, and a part-time job as given in Table 10. For class standing, the students in their first 2 years were considered as underclassmen, and the others were considered as upperclassmen. As per the logistic regression results, international experience, high academic engagement, and class standing were identified as significant variables ($p < 0.05$), whereas gender and part-time job were not significant ($p > 0.05$). International experience and high academic engagement may depend on class standing as upperclassmen may find more opportunities to participate in extracurricular activities. The logistic regression was also conducted for each class standing level independently. As given in Table 10, international experience was identified as a significant factor for both levels of class standing ($p < 0.05$), and high academic engagement was only for the lowerclassmen. Student traits such as high academic engagement and international experience are expected to be associated with the global awareness measures considered in this study. It is also tenable that participants with some type of international experience had a higher level of interest in global issues. However, it should be noted that this group of participants demonstrated not only very high levels of interest but also performed very well in the knowledge and strategic processing tests. To investigate the relationships among the variables, a correlation analysis was carried out. Nonparametric Spearman correlations among the variables given in Table 11 indicated positive relationships among the variables, particularly significant at the proficiency level. Further, cluster II scores were higher than cluster I scores for all variables considered in this study, particularly at the proficiency level as demonstrated with the ANOVA results displayed in Table 6. As we discuss in the following section, these findings are important for answering our research question.

Discussion

With respect to our research question, the participants clustered in the high global awareness category had higher levels of knowledge, strategic processing, and interest in global issues. Our findings showed that international experience had a positive relationship with not only interest and knowledge but also strategic processing as predicted by the MDL: 76.92% of the participants with some form of international experience are in the high global awareness cluster (cluster II) as shown in Table 9. This finding has important implications in terms of validating the predictions of the MDL in the context of global awareness. The MDL posits that learners develop

Table 10 Results of the logistics regression

		Logistics regression results					Likelihood ratio tests		
		b	*std*	*Wald*	*df*	*p*	*K*	*df*	*p*
All class levels	Intercept	− 1.61	.35	20.51	1	< .001	0	0	
	High academic engagement	0.51	.23	4.79	1	.028	4.77	1	.029
	International experience	1.48	.28	26.99	1	< .001	29.82	1	< .001
	Class standing	0.44	.22	3.88	1	.049	3.86	1	.049
	Gender	0.33	.26	1.55	1	.212	1.55	1	.213
	Part-time job	− 0.41	.21	3.64	1	.056	3.67	1	.055
Underclassmen	Intercept	− 1.22	.46	6.89	1	.009	0	0	
	High academic engagement	0.49	.30	2.73	1	.098	2.70	1	.100
	International experience	1.34	.38	11.94	1	.001	12.71	1	0
	Gender	0.37	.36	1.06	1	.302	1.05	1	.304
	Part-time job	− 0.14	.26	0.30	1	.584	0.300	1	.584
Upperclassmen	Intercept	− 1.38	.53	6.70	1	.010	0	0	
	High academic engagement	0.48	.38	1.56	1	.211	1.56	1	.211
	International experience	1.60	.43	14.29	1	< .001	16.32	1	< .001
	Gender	0.36	.41	0.54	1	.450	0.55	1	.458
	Part-time job	− 0.94	.37	6.27	1	.012	6.405	1	.011

Table 11 Non-parametric Spearman correlations among the variables

Variable	KA	KC	KP	SPA	SPC	SPP	EIC	EID	IIE	IIF
Knowledge acclimation (KA)	1	.518**	.373**	.223**	.099*	.159**	.332**	.131**	.111*	.267**
Knowledge competency (KC)		1	.547**	.194**	.079	.125*	.392**	.108*	.057	.340**
Knowledge proficiency (KP)			1	.238**	.123*	.219**	.307**	.228**	.230**	.363**
Strategic processing acclimation (SPA)				1	.356**	.316**	.198**	.149**	.251**	.273**
Strategic processing competency (SPC)					1	.310**	.179**	.168**	.182**	.210**
Strategic processing proficiency (SPP)						1	.280**	.295**	.305**	.334**
Engagement interest-casual (EIC)							1	.467**	.352**	.577**
Engagement interest-deliberate (EID)								1	.453**	.390**
Intentional interest-easy (IIE)									1	.601**
Intentional interest-effortful (IIF)										1

*Significant at the 0.01 level (2-tailed)
**Significant at the 0.05 level (2-tailed)

their expertise in a domain through changes in three dimensions: knowledge, strategic processing, and interest. According to the MDL, these changes follow a common pattern regardless of the domain as discussed in (Alexander et al., 1995; Alexander et al., 1997; Alexander et al., 2004; Murphy & Alexander, 2002).

In this study, the participants in the high global awareness cluster, who have demographical/academic background as well as extracurricular experiences not only performed well at the proficiency level knowledge and strategic processing questions but also exhibited a much higher individual interest in developing their global awareness. Certainly, we cannot label these participants experts in global issues/matters. Their scores in all three domains of the MDL followed the patterns predicted by the MDL, and their backgrounds matched their performance, supporting the applicability of an MDL-based instrument for assessing global awareness. Therefore, educators can track the changes and interplay among knowledge, strategic processing, and interest to evaluate students' development in global awareness using the MDL-based instrument. In summary, we can state that the results of the cluster analysis support the validity of the MDL in two ways:

(*i*) The profiles of students in each cluster matched the expectations that curricular and co-curricular experiences contribute to building students' global awareness as expressed in the background section of the paper. The analyses in the current paper showed that the students who performed well in the three dimensions of the MDL had some form of international experience.

(*ii*) Strong relations were observed among the knowledge, strategic processing, and interest variables. To further support this observation, Table 11 presents non-parametric Spearman correlation coefficients among the knowledge, strategic processing, and interest variables. According to the MDL, changes in these variables are expected to be observed in parallel. Therefore, observing positive correlations among the three components of the MDL is important for supporting the use of the MDL-based instrument to assess students' development in global awareness. Especially, the observed positive correlations between the proficiency level knowledge and the interest variables are noteworthy. These results have supported the notion that as students gain more knowledge, they also develop a higher level of individual interest in global awareness.

Regarding a curricular perspective, the findings suggest the importance of engaging engineering students in extracurricular activities to instill global awareness in them. The activities listed in the high academic engagement category, such as double major, enrolled in a minor, and participating in undergraduate research, not only indicate that the students in the high global awareness cluster were academically driven but they also try to broaden their educational experiences by enrolling in a minor or conducting undergraduate research. As our results showed, these academic activities were a factor determining the cluster membership of participants in the first two years of their education. Note that academic indicators such as being an honor student or on dean's list were found to be indifferent between the two clusters.

Clearly, having an international experience was the most common attribute among the participants who were grouped in the high global awareness cluster. The benefits of exposing engineering students to international experiences and collaborations are numerous: promoting collaborative problem-solving skills, encouraging students to formulate problems differently, and devising solutions considering important human dimensions (Downey et al., 2006; Zou & Mickleborough, 2015, Levonisova et al., 2015). In the current study, we provide empirical evidence on the impact of such experiences on

student professional development in the domain of global awareness. International experiences, such as study abroad, might help students improve their communication skills in addition to increasing students' marketability not only in engineering but across the board.

Wheatley et al. (2017) demonstrated how an international fellowship experience of engineering students improved their technical, teamwork, and cultural competencies. Although engineering programs involve a very structured and heavy set of courses, universities make an effort to provide their students with international experiences. For example, May et al. (2015) initiated a collaboration where students from the Technical University (TU) Dortmund, Germany, and the University of Virginia, USA, took part in an online synchronous course and worked together on global topics; as a result, the study discussed how interactive online role-playing simulations support students in gaining the global competency skills required to actively participate in today's international workforce. Moreover, Lattuca et al. (2017) point out that co-curricular activities and international experiences promote interdisciplinary thinking, therefore, help develop interdisciplinary competence.

The findings of this study are also in line with the other studies suggesting (*i*) learning to become a global citizen is a process, and educating all students as global citizens and work-ready employees is closely aligned to universities' international education agendas (Lilley et al., 2015); (*ii*) efforts like engaging students in cross-cultural and intercultural online projects significantly increase students' intercultural communication skills and knowledge (Kang et al., 2017); and (*iii*) cultural intelligence was predicted by agreeableness and openness, as well as a multicultural upbringing, foreign language ability, and an international orientation (Harrison, 2012). Moreover, the contribution of this paper is to support these earlier findings and discussions with an empirical data analysis.

Limitations

It is worth noting a few limitations in our research which we plan to address in our future research. The first limitation of this study is that all measures used are respondents' self-reports. Second, participation in the study was voluntary, and therefore, the students who completed the study might have already had an interest in global issues. Third, students' global awareness skills were assumed to be resulted, at least partly, from their engagement in the university environment, namely, students' curricular and students' co-curricular participation. Other environmental factors, such as program size, available resources, and the degree of students' interactions with peers and faculty, could also be considered. Fourth, the data were collected in a cross-sectional study at a one-time point, not through a longitudinal study. Therefore, we could not answer whether individual students' global awareness improved during their education. Finally, the data collection was limited to one geographically dispersed institution. In order to make our results generalizable, we will plan to collect and analyze data from different institutions. Including some community colleges and minority-serving institutions in our data collection will be another remedy for this limitation as well.

Conclusion and future research

Based on the data analysis, students' international experiences seemed positively related to not only interest and knowledge, but also strategic processing predicted by the Model of Domain Learning (MDL). The finding of this study shows that engineering students with international experience and high academic engagement (i.e., double major, enrolled in a minor and participating in undergraduate research) tend to have higher knowledge and an increased interest in global awareness. Hence, higher education institutions should consider making pedagogical interventions in their programs to effectively embed international experience into students' curriculum. This will lead to a future research avenue of how the developed instrument can be used to study if students' development in global awareness influences their future career choices and outcomes. In addition, the implementation of the findings in other disciplines, such as Education and Social Sciences, will be an interesting extension of the research.

Abbreviations

STEM: Science, technology, engineering and mathematics; MDL: Model of Domain Learning; ABET: Accreditation Board for Engineering and Technology; CR: Composite reliability; KR-20: Kuder-Richardson Formula 20; AVE: Average variance extracted; HTMT: Heterotrait-monotrait ratio; CFA: Confirmatory factor analysis

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Author's contributions

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Availability of data and materials

The dataset used and analyzed in this study is available from the author on a reasonable request.

Competing interests

The author declares that she has no competing interests.

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