Global Journal of Engineering Education

Assessing students' foundation skills prior to the STEM majors

Anthony Rhodes†, Maurice M. Danaher† & Ashley Ater Kranov‡

Zayed University, Abu Dhabi, United Arab Emirates†
Princess Nourah bint Abdulrahman University, Riyadh, Kingdom of Saudi Arabia‡

ABSTRACT: To increase the employability of STEM graduates and their readiness as scientific and technical knowledge workers for the 21st Century knowledge economies, higher education must emphasise what are known as foundation skills, such as critical thinking, quantitative reasoning, communication and teamwork, to name a few. Quality assurance organisations, such as ABET (the international accrediting body for technical fields) and national higher education accrediting bodies require programmes to show evidence of student attainment of foundation skills. Such skills, however, are recognised as difficult to both teach and assess. In earlier articles, the authors have described and presented preliminary results and findings from an assessment framework - the General Education Foundation Skills Assessment (GEFSA) - used to measure and assess the attainment of foundation skills for non-native English speaking students in a general education programme (i.e. pre-major students) at Zayed University in the United Arab Emirates. This article focuses on recent GEFSA testing with students in their first and last semesters of the general education programme.

Keywords: Rubric, 21st Century skills, transferable skills, measurement, performance task, soft skills

INTRODUCTION

The foundation skills required by employers of any graduate to enable them to successfully embrace the opportunities offered in the 21st Century workplace are life skills (communication skills, teamwork and leadership skills, language skills in reading and writing, information literacy), transferable skills (such as problem-solving including critical thinking, creativity, quantitative reasoning) and technology skills (search for knowledge and build upon it) [1][2]. STEM graduates require sophisticated problem solving, critical thinking and quantitative reasoning skills. They need to be able to work in project teams sometimes assuming leadership roles. They need to communicate (written and oral forms) in the language of their discipline to varied audiences. They require an awareness of the impact of global issues relevant to their discipline. They need to be lifelong learners who are aware of the limitations of their discipline and therefore continually seek new knowledge [3].

Youth unemployment (ages 15-25) is a serious issue worldwide with global unemployment rates at 12.6% [1]. Exacerbating the unemployment problem, according to the United Nations Development Program (UNDP) [1], numerous reports point to a notable misalignment between the knowledge and skills demonstrated by university graduates and the competencies demanded by employers. In the UAE employers said they value foundation skills more than specific disciplinary skills [4]. Unfortunately, these are learning outcomes in which students in the region, and the UAE in particular, are especially weak [1]. To address this skills gap educational systems need to be aligned with, and respond to, the needs of the labour market [1][5].

Zayed University (ZU) is located in the United Arab Emirates (UAE), where the government has been proactive in attempts to encourage current and future youth employment. In 2010, the UAE government charted the UAE 2021 National Vision [6]. This vision is supported by four pillars, one of which is a competitive knowledge economy. As such, the UAE recognised that knowledge economies are/will be at the centre of the 21st Century knowledge societies. Knowledge society economies require graduates with strong foundation skills to become the knowledge workers driving economical and societal success [1].

To increase the success of STEM-related graduates in becoming the future knowledge workers of UAE knowledge economy workplaces, tertiary education must address the development of foundation skills mentioned. The issue is that employers value these skills, students do not attain them at adequate levels, and they are difficult to teach and measure [7].

Extant instruments evaluate each skill individually. Measurement tools designed independently of one another are insufficient for data-driven curriculum decision making. These limitations make it difficult to conduct accurate and actionable assessment of skills attainment.

The research work presented here is centred on the General Education Foundation Skills Assessment (GEFSA), a performance assessment that enables concurrent skill elicitation and evaluation as directly as possible. In addition to evaluating the students' level in the targeted skills, the method develops these skills in the students, because it elicits a performance. The GEFSA consists of 1) a scenario describing an unresolved contemporary issue, which prompts students to engage in an on-line discussion; and 2) a task-specific analytic rubric to assess the extent to which students attain the foundation skills. In addition to being useful for the general education programme, the ZU degree granting colleges can use this data to inform curricula and facilitate student transition from general education to individual majors. The GEFSA is described in an earlier article and results are provided from the pilot study [8]. This article focuses on GEFSA implementations in Spring 2017 and Fall 2016 with students in their first semester and third semesters i.e. the first and last semester of the general education programme.

GEFSA CONTEXT

Zayed University has a set of institutional learning outcomes (ZU learning outcomes or ZULOs), which all students should attain by graduation. They are used by colleges to assess students as they progress, and for both continuous improvement and quality assurance reporting purposes, and to guide programme curriculum development. The six ZULOs are: Information Literacy (IL), Technological Literacy (TL), Critical Thinking and Quantitative Reasoning (CTQR), Global Awareness (GA), Language (LA) and Leadership (LS).

ZU University College (UC) is responsible for teaching and assessing based upon the ZULOs over the course of the three-semester general education programme. Because the ZULOs are institutional learning outcomes, they are necessarily broad, which makes it challenging for instructors to design learning interventions and assessments for meaningful measurement of ZULO attainment in courses. As a response to this challenge and the other challenge outlined in the previous section of measuring skills concurrently this research has developed the GEFSA, a performance assessment that is directly aligned with the ZULOs.

The aim of the GEFSA is to provide a direct method that can be used to facilitate and measure student attainment of foundation skills aligned with the ZULOs. The GEFSA evaluates six foundation skills and they are shown in Table 1.

Table 1: The six GEFSA skills.

GEFSA A [ZULO CTQR] - Demonstrate competence in understanding and evaluating information (qualitative and/or quantitative) to solve problems and propose solutions. Definition: Students clearly frame the problem(s) raised in the scenario with reasonable accuracy and identify approaches that could address the problem(s). Students recognise relevant stakeholders and their perspectives.
GEFSA B [ZULO LS] - Interact within a group to accomplish shared goals. Definition: Students (guided by supplied prompts) work to understand the task and develop a solution. Students work together to address the problems raised in the task by acknowledging, building on, critiquing and clarifying each other's ideas to come to consensus to attain a group solution. Students encourage participation and respect of all team members.
GEFSA C [ZULO TL] - Understand and evaluate technologies and their use ethically, and where appropriate, securely in an evolving modern society. Definition: Students can understand the use, describe the responsibilities and have an awareness of the ethical issues of technology use in modern society, which may include, but are not limited to: the social and security considerations.
GEFSA D [ZULO LA] - Comprehend and communicate using academic and professional language conventions. Definition: Students adopt appropriate reading and writing strategies to communicate effectively. Students communicate clearly, coherently and concisely, with appropriate level of professional diction and tone. Students are able to develop main ideas with sufficient detail and explanation, drawing upon accurate comprehension of information. Students demonstrate accuracy of grammar and mechanics.
GEFSA E [ZULO GA] - Examine a global issue, propose solutions, and assess impact locally on individuals, organisations and society. Definition: Students analyse the local implications of both the problem and possible solutions on individuals, organisations, and society within the UAE.
GEFSA F [ZULO IL] - Locate, evaluate and use relevant information to respond to a variety of situational needs. Definition: Students refer to and examine the information and reliability of sources. Students identify what they know and do not know and show an ability to provide additional sources (primary and secondary) to support the discussion and extend their knowledge.

THE GEFSA METHOD

The GEFSA method is a performance assessment. Performance assessments are intended to directly prompt and measure the skills necessary for deep learning by asking participants to solve real-world problems. Participants in a performance

assessment demonstrate their knowledge and skills by engaging in a process and/or constructing a product [9]. There are three parts to a performance assessment: 1) a task that prompts the performance; 2) the performance (i.e. the artifact to assess); and 3) a criterion-referenced measurement tool, such as a rubric, to measure the quality of the performance [9].

The GEFSA includes: 1) a scenario and prompts as the on-line discussion task; 2) the student group discussion as the artifact; and 3) the GEFSA rubric as the criterion-referenced instrument to measure the quality of the student group performance of foundation skills. To strengthen the usability and quality of the performance assessment, four support instruments were developed: scenario development guidelines, scenario prompts, a student survey tool and a faculty survey tool. The GEFSA is an adaptation of the Computing Professional Skills Assessment (CPSA) that was developed by the ZU College of Technological Innovation and which is based on the ABET (Accreditation Board for Engineering and Technology) computing student outcomes [10].

The method is conducted by giving a group of four to five students a scenario to discuss on-line for 14 days. Following the discussion activity, the transcripts of the discussion are evaluated by the rating team using the rubric. Scenarios consist of 600-700 words describing a current issue, such as renewable energy, e-waste, climate change or cybersecurity. They were created by the research team using strict criteria and conform to a Level 12 Flesch-Kincaid readability scale, essential for students working in a second language. Local and global technology related content, the perspectives of various stakeholders and overarching issues, such as security or privacy are integral to the scenarios regardless of the specific topic. Each scenario has a set of prompts developed to guide the students through the performance task. An example of a scenario, which has elicited meaningful discussion may be found in the paper by Schoepp et al [11].

As the students had never participated in a similar type of educational activity, the process is supported by in-class activities and a trial run of the on-line discussion to familiarise students with the task. At the initial presentation the method is explained and then groups of students discuss a scenario. This is followed by a 14-day semi-guided on-line discussion facilitated by the instructor to ensure participation and on-task responses. Students are given instructions on how to interact and postings are required for task fulfilment. During the trial run, the instructor provides guidance in the on-line discussion, with the goal of preparing students to undertake an independent student-led discussion. Students become conversant with the process and the expectations of this performance task. The activity is a mandatory graded course requirement.

Following the trial run, a new scenario is given to students and the discussion runs over 14 days with the instructor monitoring, but not participating. The student discussion is then evaluated by an evaluation team using the GEFSA rubric who participate in a calibration process aiming for levels of consensus between raters of 70% or greater. All differences between raters are discussed at length so as to try and reach consensus. To arrive at the final ratings, scores from individual rates are calculated for the mean, with rounding applied, to generate overall scores for the student performance. During the discussion, notes are also made on areas for improvement of the rubric. An example of the results from a rating session may be found in the book by Johnson et al [9].

GEFSA ITERATIONS AND FINDINGS

During 2015, the two main components of the method were developed - scenarios and the rubric, and additionally support instruments - scenario creation guidelines and surveys. The rubric was created by taking the CPSA rubric as a starting point and then modifying it to align with the GEFSA skills. The GEFSA rubric has a scale of 0 to 3, where 0 is null performance and 1 to 3 correspond to emerging, developing and practicing. An example of the rubric for GEFSA skill C is shown in Table 2.

Table 2: Rubric for GEFSA skill C.

GEFSA C [ZULO TL] Understand and evaluate technologies and their use ethically, and where appropriate, securely in an evolving modern society.				
	0 - Missing	1 - Emerging	2 - Developing	3 - Practicing
Ethical/social/security considerations	Students have no awareness of how technology can be used to address an identified need. Students do not identify ethical, societal and/or security considerations.	Students become aware of how technology can be used to address an identified need. Students become aware of the ethical, societal and/or security considerations related to technology use.	Students have an understanding of how technology can addressing an identified need. Students have an understanding of ethical, societal and/or security considerations related to technology use.	Students are able to articulate how technology can address an identified need. Students articulate the ethical, societal and/or security considerations related to technology use.

In Spring 2016, the method was pilot tested with 47 students in two 3rd semester classes. The results of the trial are reported by Rhodes et al [8]. The pilot results showed that the method can measure all the skills. Additionally, both faculty and students alike were convinced that the method helps to develop and improve the foundation skills. Areas for improvement in the rubric emerged from the rating process and it was also noted that the prompts could be improved.

Following the pilot run, amendments were made to the GEFSA rubric and changes were made to the prompts to ensure alignment with the six targeted foundation skills. The authors also found that the rubric did not adequately differentiate between levels, because: 1) rubric scale levels 1 and 2 shared common criteria descriptors; and 2) the criteria descriptors were sometimes ambiguous and/or inadequately detailed for a rater to confidently assign a score. To address this, descriptors were rewritten for each rubric level and reviewed to ensure vertical alignment across rubric outcomes and levels, as well as horizontal alignment as articulated across the levels 0, 1, 2 and 3 for each outcome and performance indicator. This was done for each of the six skills.

In Fall 2016, the GEFSA was implemented twice over 14-day periods in two classes totaling 45 3rd semester general education students with scenarios on the topics of 1) e-waste; and 2) cybersecurity. The discussion transcripts were evaluated for the extent to which student attained the foundation skills. Additionally, the research team was keen to determine whether the modifications made to student prompts and to the rubric as described above were effective and/or whether further refinements were needed. As the students were in the last semester of their general education studies, the expectations were that the results would be in the lower end of the range 2 to 3. The results from the revised GEFSA rubric are shown below in Table 3. The levels of achievement scores are higher than those from the run in Spring 2016. This may be due to the modification and refinement of the rubric and the amendments to the prompts given to the students.

Table 3: Results from Fall 2016 run of GEFSA with 3rd semester students.

Skill ZULO	A CTQR	B LS	C TL	D LANG	E GA	F IL
GEFSA score	2.22	2.17	2.00	2.44	1.56	1.94

Student attainment of skills A, B and D (problem-solving, leadership and language) reached the targeted range. Students scored a 2 for skill C (technological literacy), which is borderline. Attainment levels for skills E, F were lower than the target, indicating areas for improvement in global awareness and information literacy. This indicates that a pedagogical intervention is needed to investigate a possible underlying curriculum gap causing the low achievement. The team believed that the modifications to the prompts and the amendments to the rubric were successful in improving the GEFSA. The team also noted while rating the transcripts any aspects of the rubric that should receive attention in the next refinement round.

In Spring 2017, the research targeted 1st semester students. The research team were interested to see the differences in attainment levels on the rubric compared with 3rd semester students. It was expected that there would be discernible differences in attainment levels of 1st semester students compared to the 3rd semester students. The authors expected average ratings for foundation skills of 1st semester students to be around 1 (emerging) as they are making the transition from secondary to tertiary education. The activity was conducted twice over 14-day periods in two classes totaling 30 1st semester students using scenarios on issues concerning 1) obesity and its economic effect; and 2) cybersecurity. The second scenario was the same one used in Fall 2016, though it does not matter for comparison purposes on the rubric, which scenario is used. As before, the discussion board student transcripts were analysed for student performance and also to determine what further refinements to the rubric were needed. The same version of the rubric was used as for Fall 2016.

The results from the rubric are given below in Table 4 and reveal (as expected) lower levels of skill achievement compared to 3rd semester students. These results provide additional evidence of the validity of the rubric.

Table 4: Results from Spring 2017 run of GEFSA with 1st semester students.

Skill ZULO	A CTQR	B LS	C TL	D LANG	E GA	F IL
GEFSA score	0.50	0.60	0.80	1.70	0.73	0.80

Students performed best in skill D - Language - with some students exhibiting language skills, which are well developed for a 1st semester student. They performed worst in skill B - leadership and teamwork - showing that although students were in groups, the interaction between them did not advance solutions to the scenario issues. Students generally struggled with the remaining skills (critical thinking, use of technology to address problems, awareness of local impact of global issues, the need to query information and to seek new information).

STUDENT FEEDBACK

Although this method was designed for assessment of the foundation skills, it provides a significant opportunity for students to develop and practice these skills. Students spend considerable time working on the task - two periods of 14 days and, additionally, they receive coaching on the skills in advance and during the first discussion activity. At the conclusion of the second activity, students are surveyed to obtain feedback on how they perceived that the activity improved their foundation skills. This feedback can assist with refinement of the GEFSA. There are three open-ended questions within the survey. Presented below are some student responses for question 1: *What I liked about the activity* (spelling and grammar have been edited for readability) from Spring 2017.

I enjoyed working in a group and, how each of us can discuss others points of view.	*I liked how we were able to discuss with each other and we were given a chance to argue our points and provide evidence to prove them.*	*I liked the fact that we were in groups and were given a chance to read each other's points, learn from them and see their opinions.*
We were given a chance to research, learn new things and teach the rest of our group.	*I liked communicating with the students in a job and also that the communication with the teacher was improved.*	*I was able to discuss on-line and learn from students in my class who I would not normally talk with in person.*

In response to the question: *What I did not like about the activity*, no student complained about the academic value. A few complained that some team members participated minimally; thus, hampering productive discussions. In response to the question: *What changes I would like to see*, the suggestions were not negative; actually, they requested more issues to research and discuss, and having more time (as they enjoyed the group discussion). The student comments show (as in previous semesters) that they were very positive about the activity and that they believe it improved their foundation skills.

CONCLUSIONS

This article outlined how the current version of the GEFSA framework can provide a concurrent direct assessment method to measure attainment of foundation skills in general education students. The results from the most recent performance assessment tasks demonstrated that the method can measure the skills with confidence. The results indicated that the authors were able to identify areas of strength and weakness for student groups in relation to the six GEFSA outcomes. The rubric can clearly show the difference in abilities between 1st and 3rd semester students. This method can facilitate ZU students and faculty working together in developing and enhancing foundation skills in general education students. Not only is the method ideal for evaluation of the skills, but it is an excellent approach for developing and practicing foundation skills.

ACKNOWLEDGEMENTS

This research work is funded by the Zayed University Research Incentive Fund - Grant No. R15128.

REFERENCES

1. UNDP, 2014, Arab Knowledge Report: Youth and Localisation of Knowledge (2017), 5 July 2017, http://www.arabstates.undp.org/content/rbas/en/home/library/huma_development/arab-knowledge-report-20140.html
2. Prados, J.W., Peterson, G.D. and Lattuca, L.R., Quality assurance of engineering education through accreditation: the impact of Engineering Criteria 2000 and its global influence. *J. of Engng. Educ.*, 94, **1**, 165-184 (2005).
3. Sheppard, S.D., Macatangay, K., Colby, A. and Sullivan, W.M., *Educating Engineers: Designing for the Future of the Field*. San Francisco: Jossey-Bass, 2 (2009).
4. Arab Thought Foundation. Enabling Job Creation in the Arab World: a Role for Regional Integration? (2013), 5 July 2017, http://www.pwc.com/en_M1/m1/publications/enabling-job-creation-in-arab-world.pdf
5. Organisation for Economic Cooperation and Development (OECD). Better Skills, Better Jobs, Better Lives: a Strategic Approach to Education and Skills Policies for the United Arab Emirates. Paris, France: OECD Publishing (2014).
6. UAE. United Arab Emirates Vision 2021 (2010), 5 July 2017, https://www.vision2021.ae/sites/default/files/uae-vision2021-brochure-english.pdf
7. Shuman L.J., Besterfield-Sacre, M. and McGourty, J., The ABET *professional skills* - can they be taught? Can they be assessed?, *J. of Engng. Educ.*, 94, **1**, 41-55 (2005).
8. Rhodes, A., Danaher, M.M., Ater Kranov, A. and Isaacson, L., Measuring attainment of foundation skills in general education at a public university in the United Arab Emirates. *World Trans. on Engng. and Technol. Educ.*, 14, **4**, 506-512 (2016).
9. Johnson, R.L., Penny, A.J. and Gordon, B., *Assessing Performance: Designing, Scoring, and Validating Performance Tasks*. New York: The Guilford Press (2009).
10. Danaher, M., Schoepp, K. and Ater Kranov, A., A new approach for assessing ABET's professional skills in computing. *World Trans. on Engng. and Technol. Educ.*, 14, **3**, 355-360 (2016).

11. Schoepp, K., Danaher, M. and Ater Kranov, A., The computing professional skills assessment: an innovative method for assessing ABET's student outcomes. *Proc. IEEE Global Engng. Educ. Conf.*, Abu Dhabi (2016).

BIOGRAPHIES

Anthony Rhodes holds a PhD in information systems security from Queensland University of Technology (QUT), Australia. He is currently employed as Associate Dean, University College, Zayed University, United Arab Emirates, where he has oversight of academic quality assurance of the General Education programme delivered through University College to all Zayed University students. Aside from his research interests in information security (access control), he is an active researcher in teaching and learning as it relates to graduate cognitive/life skills required for the transition to the workplace from higher education. He has been at Zayed University since 2004.

Maurice Danaher is an associate professor in the College of Technological Innovation at Zayed University, United Arab Emirates. He received his PhD in computing and information systems from Swinburne University of Technology, Melbourne, Australia. His research is in the areas of information technology and education. In recent years, his research in education has moved towards issues related to quality in education. He focusses on assessment of quality, and teaching and assessing the 21st Century skills. He has extensive experience in industry and academia internationally.

Ashley Ater Kranov is an adjunct associate professor in the School of Electrical Engineering and Computer Science at Washington State University and President of the consulting firm Global Professional Skills Assessment. She is also Acting Vice-Dean of the Deanship of Electronic and Distance Learning and the College of Computer and Information Sciences at Princess Nourah bint Abdulrahman University in Riyadh, Kingdom of Saudi Arabia, the largest female university in the world. Her research areas are direct methods to teach and measure the engineering professional skills necessary for 21st Century engineering workplace success and how to increase gender equity in engineering.