

# Sustainable Practices in Technical Education: A Quality Assurance Framework\*

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The term *sustainability* means using methods, systems and materials to meet the needs of the present without compromising the future. Even with the prevalence of the term and its wide use across disciplines, there has been little effort to formulate a quality measurement framework in tertiary education based on the values and characteristics of sustainability. The framework that we present here is the Sustainability of Technical Education (SoTE), where *sustainability* is defined as the ability to continuously improve without reducing the capacity to endure. The SoTE consists of criteria, measures, indicators, and a set of aligned analytic rubrics that aid the calculation of different indicators including a one main indicator called the Sustainability Indicator. In this paper, we present the need for a focus on sustainability in higher education for continuous improvement and fiscal purposes, present the SoTE criteria and indicators, and present the results and analysis of a pilot study conducted at a private, non-profit university in the Gulf Cooperation Council (GCC) Region. The paper concludes with a discussion of the usefulness of the SoTE for continuous improvement and for collecting and providing evidence for quality assurance and accreditation organizations at programmatic and institutional levels.

**Keywords:** technical education; philosophy of engineering education; sustainability; accreditation

## 1. Introduction

Sustainability and continuous improvement are interdependent in any context, yet perhaps most notably in higher education. The term sustainability aims to describe the capacity of meeting the needs of the present without compromising the future. Continuous improvement refers to the ability and capacity to learn, change and grow in response to input [1–6]. From core course offerings in general education and foundation years through program, college and institutional levels, sustainability in the context of continuous improvement is key to student success, faculty satisfaction and performance, and stakeholder belief in and support of tertiary education. Numerous outcomes-based quality assurance and accrediting bodies worldwide include demonstration of sustainability indicators and continuous improvement as performance criteria. Sustainability in higher education is necessary to successfully navigate risks, turn challenges into opportunities, address increasing fiscal restrictions, and ensure a strong infrastructure for future development. The SoTE is the first comprehensive quality assurance framework in the literature that can be used to guide and measure sustainability at program, college and institutional levels for continuous improvement purposes. This framework can be used by programs, colleges and institutions to guide them in system-wide development and measurement of policies,

practices and procedures to ensure not only sustainability, but also to positively impact student, faculty and staff learning for continuous improvement purposes. Here, technical education is concerned with Engineering, Engineering Technology, Computing, and Applied Science.

Quality assurance in higher education has been the target of a variety of critical reviews, framework developments, and research efforts to identify pathways for successful continuous improvement. A discussion on knowledge, methodology, and validity of outcomes of quality assurance is presented by [7] within the framework of organizational theory and change management. The discussion argues that quality assurance can benefit from creating a realistic picture of how organizational change takes place to provide more refined schemas. A shift in the focus of quality activities in higher education from accountability and control to improvement is suggested by [8]. The proposed shift is based on a critical review of dominant conceptions and approaches to quality in higher education. The critical review suggests that industry-born quality models are an imperfect fit to higher education. Moreover, a quality assurance framework built upon a system concept with inputs and outputs is presented in [9]. Here, higher education is the issuing of a product; the quality of the system is formulated in terms of performance and efficiency. Furthermore, the author in [10] provided a comparison

between the well-established quality assurance standard in industry, the ISO-9000, and ABET accreditation criteria EC-2000. The comparison highlighted that EC-2000 provides a systematic tool for quality assurance in technical education. The experiences and the lessons learned in the ISO-9000 field contributed to engineering education and EC-2000 by providing a focus on processes, documentation and training, and the need to reevaluate faculty reward systems.

The term *Sustainability* is used in business, management, biology, ecology, and development [9, 11–13]. The rich literature of sustainable development pre-dominates the public use of the term *Sustainability*. The practice of teaching for sustainable development is usually referred to as *Sustainability Education*, *Education for Sustainability*, or *Education for Sustainable Development* (ESD). ESD is the term adopted by the United Nations. Within an ESD context, teaching and learning aims to empower learners to behave under sustainable values [14–20].

Damaj et al. presented the first formal framework that can be used to measure sustainability within tertiary engineering education, where the focus was to define sustainability and propose a measurement framework in the higher education context [21]. In [22, 23], the application of the framework of [21] was presented for a pilot study related to governance and management and the sustainability of academic programs. In this paper, we adopt and expand the

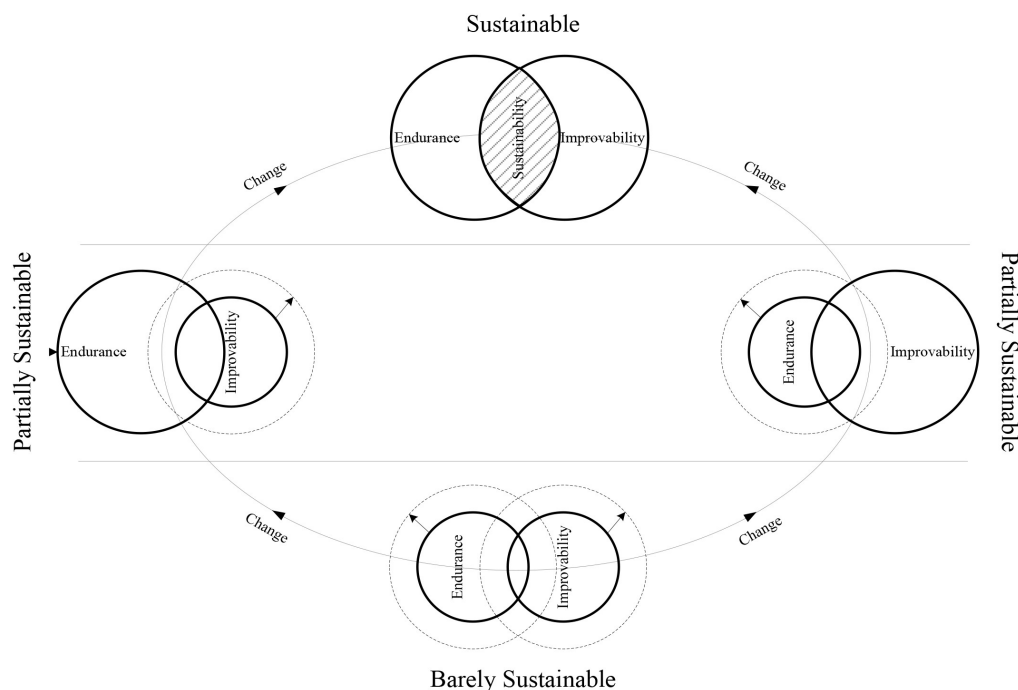
definitions of sustainability and build on the results and analysis from [21–23] to present a nine-criteria measurement framework.

This paper is organized so that Section 2 extends the definitions of sustainability. Section 3 presents the research goals and questions. Section 4 presents the measurement framework with the full set of criteria, measures, indicators, and sample rubrics. In Section 5, we present the statistical model of the Sustainability Indicator, and a portfolio of other indicators that covers complementary aspects of SoTE. The results of the pilot study are presented in Section 6. General evaluation, challenges and limitations of the presented work, and comparison with closely related work are presented in Section 7. Section 8 concludes the paper and sets the ground for future work.

## 2. Defining the sustainability of education

In terms of education, Damaj et al. define *Sustainability* in [21] as the ability to continuously improve without reducing the capacity to endure. At the system level, the educational institution should be able to improve without reducing its ability to endure. The institution should adopt an approach that strives to produce professionals that have sustainable values.

In Fig. 1, we depict the desirable SoTE, the possible realities of being sustainable, partially sustainable, barely sustainable, and the change



**Fig. 1.** The two objectives of SoTE are *Improvement* and *Endurance*; the desirable sustainability shown at the top, the reality of being *Partially* or *Barely Sustainable*, and the change needed in the direction of *Partially Sustainable* and *Sustainable* [21].

**Table 1.** The attributes table of the *SoTE* objectives [20]

Sustainability Attributes		Endurance		
		Low	Growing	Satisfactory
Improvability	Low	Unsustainable	Unsustainable	
	Growing	Unsustainable	Barely Sustainable	Partially Sustainable
	Satisfactory		Partially Sustainable	Sustainable

needed. Being partially sustainable means having a satisfactory ability to improve with a growing capacity to endure. Being partially sustainable means having a satisfactory capacity to endure with a growing ability to improve. The attribute of being barely sustainable means having growing ability to improve and capacity to endure. The attribute of being unsustainable means having low ability to improve and/or capacity to endure. The different attributes of *SoTE* are shown in Table 1. We consider the case where one objective is found to be *Satisfactory* while the other is *Low* as less likely to exist; accordingly, the corresponding area in Table 1 is left without shading and unclassified.

### 3. Research goal, objectives and questions

Our primary research goal is to formulate a quality

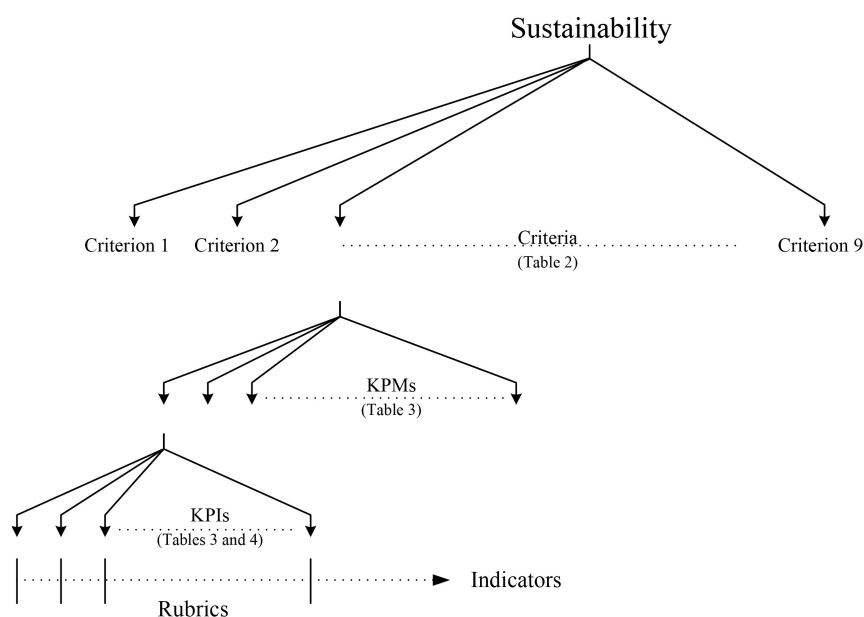
assurance framework for higher education based on the values and characteristics of sustainability. Our three research objectives are as follows:

1. Define sustainability within the context of technical higher education.
2. Create a framework for measuring sustainability comprised of criteria, indicators, rubrics, statistical formulations, and evaluation charts.
3. Deploy the framework in a pilot study using a case-study methodology [24] that targets a single institution in order to establish initial reliability and validity.

In this project, the theoretical proposition is that the presented measurement framework accurately describes the content and constructs that comprise sustainability of technical education in a higher

**Table 2.** The *SoTE* Criteria

No.	Criterion	No.	Criterion
1.	Leadership and Governance	6.	Academic Support Services
2.	Student Learning by Coursework Program	7.	Student Support Services
3.	Student Learning by Research Program	8.	Faculty and Staff Support Services
4.	Faculty Research and Consultancy	9.	General Support Services and Facilities
5.	Industry and Community Engagement		

**Fig. 2.** The measurement framework of *SoTE* (Damaj and Ater Kranov 2013).

education setting and measures the sustainability. Thus, our two research questions are as follows; this paper addresses research question 1:

1. Do the SoTE Rubric scores reliably provide information about the sustainability of education that the institution provides?
2. What is the correlation coefficient between the

SoTE Rubric scores and scores from other established instruments that measure the same or similar criteria?

#### 4. The SoTE measurement framework

The SoTE measurement framework is comprised of nine criteria, from Leadership and Governance

**Table 3.** The list of developed KPIs showing the Criteria, KPM, and KPI numbers

No.	KPM/KPI	No.	KPI
<b>1.1</b>	<b>Strategic Planning</b>	<b>5.1</b>	<b>Industry and Community</b>
1.1.1	Value and are committed to the sustainability of education	5.1.1	Cultivate relationships with the industry and community
1.1.2	Invest in quality education	<b>5.2</b>	<b>Alumni</b>
<b>1.2</b>	<b>Governance</b>	5.2.1	Cultivate alumni relationships
1.2.1	Able to Improve	<b>6.1</b>	<b>Admission</b>
1.2.2	Retain the institution head	6.1.1	Recruit Students
1.2.3	Retain academic administrators	6.1.2	Retain Students
1.2.4	Retain staff	<b>6.2</b>	<b>Registrar</b>
1.2.5	Retain faculty	6.2.1	Facilitate Registration
1.2.6	Students to faculty ratio	6.2.2	Keep records
1.2.7	Handle the effect of change of people in position	<b>6.3</b>	<b>Information Technology Services</b>
1.2.8	Benchmark against other institutions	6.3.1	Develop Plans
1.2.9	Develop faculty and staff	6.3.2	Develop Policies and Procedures
1.2.10	Balance faculty load	6.3.3	Develop infrastructure
1.2.11	Apply selective recruitment	6.3.4	Probe products and services
1.2.12	Implement a work breakdown structure with defined authority and responsibility	6.3.5	Manage organization and external relationships
1.2.13	Offer promotion opportunity	6.3.6	Ensure funding
1.2.14	Value diversity	<b>6.4</b>	<b>Student Learning Support</b>
1.2.15	Manage the change	6.4.1	Provide training opportunities for student
<b>1.3</b>	<b>Accreditation and Quality Assurance</b>	6.4.2	Assess training impact
1.3.1	Probe quality	6.4.3	Provide academic advising
1.3.2	Work on autonomy	<b>6.5</b>	<b>Teaching Resources</b>
1.3.3	Participate in institutional and professional accreditations	6.5.1	Provide general learning facilities
<b>1.4</b>	<b>Policy Management</b>	6.5.2	Maintain service per user policies
1.4.1	Develop and review policies	6.5.3	Provide major-specific learning facilities
<b>1.5</b>	<b>Entity and Activity Review Systems</b>	6.5.4	Adopt a maintenance and upgrade policy
1.5.1	Evaluates Institutional Effectiveness at the review level	<b>6.6</b>	<b>Library</b>
1.5.2	Evaluates Institutional Effectiveness at the planning level	6.6.1	Assure currency of resources and facilities
<b>1.6</b>	<b>Fundraising</b>	6.6.2	Assure sufficient resources and facilities
1.6.1	Participate in Fundraising	6.6.3	Service the community
<b>2.1</b>	<b>Program Educational Objectives</b>	<b>7.1</b>	<b>Student Activities</b>
2.1.1	Develop Program Educational Objectives	7.1.1	Incorporates sustainability outcomes into student activities
<b>2.2</b>	<b>Student Outcomes</b>	<b>7.2</b>	<b>Student Behavior</b>
2.2.1	Develop Student Outcomes	7.2.1	Adopt and apply a code of conduct
<b>2.3</b>	<b>Curriculum</b>	7.2.2	Provide counseling
2.3.1	Align curriculum	<b>7.3</b>	<b>Student Grievance</b>
<b>2.4</b>	<b>Assessment</b>	7.3.1	Provide a grievance system
2.4.1	Plan assessment	<b>7.4</b>	<b>Career and Employment Services</b>
2.4.2	Probe quality	7.4.1	Provide career planning advice and training
2.4.3	Build a culture of assessment	<b>8.1</b>	<b>Staff Professional Development</b>
<b>2.5</b>	<b>Plagiarism</b>	8.1.1	Assess training needs, and provide and organize professional training
2.5	Control plagiarism	<b>8.2</b>	<b>Staff Promotion and Incentives</b>
<b>3.1</b>	<b>Research Program</b>	8.2.1	Adopt reward and promotion systems
3.1.1	Probe Quality	<b>8.3</b>	<b>Faculty and Staff Organizational Climate and Retention</b>
3.1.2	Align research objectives with the National, Regional, and International Research Directions	8.3.1	Measure, maintain, and improve satisfaction
3.1.3	Provide research facilities	8.3.2	Adopt and apply a code of conduct
3.1.4	Provide quality supervision	8.3.3	Provide a grievance system
<b>3.2</b>	<b>Student Research Support</b>	<b>9.1</b>	<b>Campus Services</b>
3.2	Provide and pursue research funds	9.1.1	Has a Campus
<b>4.1</b>	<b>Faculty Research</b>	9.1.2	Probes Quality
4.1.1	Align research objectives with the National, Regional, and International Research Directions	9.1.3	Improve the Campus
4.1.2	Probe Quality	<b>9.2</b>	<b>Public Relations</b>
<b>4.2</b>	<b>Professional Development for Research</b>	9.2.1	Assess the market
4.2.1	Implement a Professional Development System	9.2.2	Engage the market
<b>4.3</b>	<b>Consultancy Activities</b>	9.2.3	Publish university materials
4.3.1	Observe consultancy activities as professional development	-	-
<b>4.4</b>	<b>Research-Teaching Nexus</b>	-	-
4.4.1	Incorporate research and scholarly activities in the learning process	-	-

**Table 4.** Analytic Version of the SoTE Rubric: Criterion 4 with select KPMs (M) and KPIs (I)

Criterion		Criterion 4 – Faculty Research and Consultancy			
General		Rubric (Nascent: Below the Beginning level, Beginning, Developing, Competent, Accomplished)			
M	I	Beginning	Developing	Competent	Accomplished
4.2. Professional Development for Research	4.2.1. Implement a Professional Development System	Faculty research support is limited and rare. Research is poorly promoted according to its scholarly merit, completeness, feasibility, and need. Pursue of funds is ill-administered. Community engagement and outreach play very little role in facilitating the pursue of funds.	Faculty research is adequately and occasionally supported. Research is partially promoted according to its scholarly merit, completeness, feasibility, and need. The pursuit of internal and external funds is administered; the pursuit is facilitated by community engagement and outreach.	Faculty research is soundly and frequently supported. Research is promoted according to its scholarly merit, completeness, feasibility, and need. The pursuit of internal and external funds is adequately administered; the pursuit is facilitated by effective community engagement and outreach.	Faculty research is extensively and consistently supported. Research is well-promoted according to its scholarly merit, completeness, feasibility, and need. The pursuit of internal and external funds is well-administered; the pursuit is always facilitated by highly effective community engagement and outreach.
4.3. Consultancy Activities	4.3.1. Observe consultancy activities as professional development	Faculty external consultancy activities are little recognized according to merit, currency, and relevancy. Consultancy activities are minimally rewarded (e.g. by reducing teaching load, financial support, etc.). External consultancy experiences rarely feed-back into curriculum, activities, and research.	Faculty external consultancy activities are somehow recognized according to merit, currency, and relevancy. Consultancy activities are sometimes rewarded (e.g. by reducing teaching load, financial support, etc.). External consultancy experiences occasionally feed-back into curriculum, activities, and research.	Faculty external consultancy activities are adequately recognized according to merit, currency, and relevancy. Consultancy activities are soundly rewarded (e.g. by reducing teaching load, financial support, etc.). External consultancy experiences frequently feed-back into curriculum, activities, and research.	Faculty external consultancy activities are highly recognized according to merit, currency, and relevancy. Consultancy activities are thoroughly rewarded (e.g. by reducing teaching load, financial support, etc.). External consultancy experiences continuously feed-back into curriculum, activities, and research.
4.4. Research-Teaching Nexus	4.4.1. Incorporate research and scholarly activities in the	Poor, weakly-related, and rarely updated research-teaching reciprocation. The research-teaching nexus is ill-planned, ill-distributed throughout the curriculum, and/or not observed in research activities.	Acceptable, somewhat related, and occasionally updated research-teaching reciprocation. The research-teaching nexus is adequately planned, distributed throughout the curriculum, and/or observed in research activities.	Proficient, well-related, and frequently updated research-teaching reciprocation. The research-teaching nexus is well-planned, distributed throughout the curriculum, and observed in research activities.	Exemplary, complementary, and continually updated research-teaching reciprocation. The research-teaching nexus is precisely planned, distributed throughout the curriculum, and clearly observed in research activities.

to General Support Services and Facilities, 34 key performance measures (KPMs) and one or more key performance indicators (KPIs) for each KPM; see Table 2 for the criteria and Fig. 2 for the framework [21]. The SoTE Rubric, comprised of the nine criteria, can be used to measure the extent to which an institution has attained the given set of KPMs and KPIs. Table 3 presents the full list of KPMs and KPIs, and Table 4 presents the SoTE Rubric of Criterion 4, Faculty Research and Consultancy. Two versions of the SoTE Rubric were developed: analytic and holistic. The analytic version provides more detailed descriptors for each criterion by level and the holistic version provides a streamlined set of descriptors; see the two versions for Criterion 4, Faculty Research and Consultancy, in Table 5. In addition, because each of the criteria are of equal weight, users can calculate one main Sustainability Indicator (*SI*).

The SoTE Rubric uses the scale labels: *Nascent*, *Beginning*, *Developing*, *Competent*, and *Accomplished*. The design rationale of every KPI is area-specific and required deep understanding of the

technicalities of the measured area. To ensure that the SoTE Rubric descriptors were as accurate as possible, we consulted experts in the field and conducted an extensive literature review, including a review of existing rubrics with similar constructs, but which had different goals or applications (thus the rationale for our development of a new measurement framework).

## 5. The statistical model

The SoTE Sustainability Indicator, or *SI*, is the statistical composition of all the nine criteria, the KPMs and the KPIs. The values for each of the scale level are: 1 = *Nascent*, 2 = *Beginning*, 3 = *Developing*, 4 = *Competent*, and 5 = *Accomplished*. The values are then each divided by measurements from a reference institution for normalization and for producing performance ratios calculated per the formula in Equation 1. Combined indicators, such as the *SI*, is then calculated as the Geometric Mean of ratios (See Equation 2).

$$ratio_l = \frac{KPI_{k,j,i,l}}{KPI_{k,j,i,l}^{ref}} \quad (1)$$

where  $ratio_l$  is the  $l^{th}$  ratio and  $l \in \{1..n\}$   
of the  $k^{th}$  Criterion,  $j^{th}$  KPM, and the  $i^{th}$  KPI  
 $KPI_{k,j,i,l}^{ref}$  is the reference measurement of the  
indicator  $KPI_{k,j,i,l}$

Then, the  $SI$  is the Geometric Mean [18, 19] of all  $n$  ratios:

$$SI = \sqrt[n]{ratio_1 \times ratio_2 \times \dots \times ratio_n} \quad (2)$$

The Geometric Mean is used for combining indicators as it can measure the central tendency of data values that are obtained from ratios. Using the

Geometric Mean ensures two important properties [25–27]:

1. The Geometric Mean of the ratios is the same as the ratio of Geometric Means
2. The ratio of the Geometric Means is equal to the Geometric Mean of performance ratios; which implies that when comparing two different institutions' performance, the choice of the reference institution is irrelevant.

In this investigation, we introduce a set of complementary indicators for SoTE based on combining specific criteria. The combined indicators and their Geometric Mean are shown in Table 6. At the inter-criteria level, we define a set of indicators that comprises selected measurements across the

**Table 5.** Sample KPMs (Ms), KPIs (Is), and Rubric from Criterion 4, Table (a) presents a sample analytic rubric, and (b) presents a sample holistic rubric

(a)

Criterion		Criterion 4 – Faculty Research and Consultancy			
General		Rubric (Nascent: Below the Beginning level, Beginning, Developing, Competent, Accomplished)			
M	I	Beginning	Developing	Competent	Accomplished
4.1. Faculty Research	4.1.2. Probe Quality	Research objectives are ad hoc.	Research objectives are in few instances aligned with national objectives. There is a growing interest in understanding the regional and international research directions.	Research objectives are mainly aligned with national objectives. A few objectives meet the regional and international goals.	Research objectives are continuously aligned with national, regional, and international research objectives (e.g. Millennium development goals of the United Nations)
	4.1.2. Probe Quality	The research quality falls below the standard of nationally recognized work.	The research quality is mainly recognized nationally in terms of originality, significance, and rigor. There is discussion for defining quality research in terms of faculty profile, administration structure, policies, and strategies for continuous research development.	The research quality is internationally excellent in terms of originality, significance, and rigor but which nonetheless falls short of the highest standards of excellence. Quality research is maintained by high-profile faculty. The research environment is administered by a clear structure, policies, and strategies for research development. Research is in continuous development.	The research quality is world-leading in terms of originality, significance and rigor. Quality research is maintained by high-profile faculty, support staff, and assistants. The research environment is stimulating and administered by an effective structure, policies, and strategies for research development. The research is in continuous development based on quantitative analysis, and qualitative information on research performance and measures of esteem.

(b)

Criterion		Criterion 4 – Faculty Research and Consultancy			
General		Rubric (Nascent: Below the Beginning level, Beginning, Developing, Competent, Accomplished)			
I		Beginning	Developing	Competent	Accomplished
Faculty Research		The research quality falls below the standard of nationally recognized work. Research objectives are ad hoc.	The research quality is mainly recognized nationally in terms of originality, significance, and rigor. There is discussion for defining quality research. Research objectives are in few instances aligned with national objectives. There is a growing interest in understanding the regional and international research directions.	The research quality is internationally excellent in terms of originality, significance, and rigor but which nonetheless falls short of the highest standards of excellence. Research is in frequent development. Research objectives are mainly aligned with national objectives. A few objectives meet the regional and international goals.	The research quality is world-leading in terms of originality, significance and rigor. The research is in continuous development. Research objectives are continuously aligned with national, regional, and international research objectives (e.g. Millennium development goals of the United Nations).

**Table 6.** Combined indicators and their Geometric Mean (GM) compositions

Indicator	Acronym	GM Composition
Leadership and Governance Sustainability Indicator	LGSI	All indicators under Criterion 1
Student Learning Indicator	SLSI	All indicators under Criteria 2 and 3
Research Sustainability Indicator	RSI	All indicators under Criteria 3, 4, and 5
Support Services Sustainability Indicator	Triple-SI – TSI	All indicators under Criteria 6, 7, 8, and 9

**Table 7.** Combined indicators at the inter-criteria level and their Geometric Mean (GM) compositions

Indicator	Acronym	GM Composition
Community Engagement Sustainability Indicator	CESI	All indicators under Criterion 5; KPMs 1.6, 3.2, 4.3, 6.1, 6.6, 7.4, and 9.2; and KPIs 3.2.1 and 4.1.1
Quality Review Sustainability Indicator	QRSI	All indicators under KPMs 1.1, 1.3, 1.5, and 2.4; and KPIs 1.2.8, 3.1.1, 4.1.2, 6.3.4, 8.3.1, 9.2.1, and 9.2.2
Facilities Sustainability Indicator	FSI	All indicators under KPMs 1.5, 1.6, 3.2, 4.2, 5.1, 6.3, 6.4, 6.5, 6.6, and 9.1; and KPIs 3.1.3 and 6.2.1
Information Technology Sustainability Indicator	ITSI	All indicators under KPM 6.3

KPMs and KPIs (See Table 7). The free choice of combinations of indicators at various levels demonstrates the flexibility of the proposed framework.

Besides the set of composite indicators, the quantitative analysis includes dispersion, histogram, kurtosis ( $\kappa$ ), and skewness ( $\varsigma$ ) analyses of measured quantities [28]. The histogram of measured quantities presents the number of responses per a scale point. Accordingly, the histogram aids the discovery of the most attained qualitative scale point. The dispersion analysis includes the standard deviation ( $\sigma$ ) of the results. The standard deviation measures the dispersion of results around the mean ( $\mu$ ) and consequently the extent of variation in the obtained results. The skewness measures the degree of asymmetry of a distribution around its mean. Positive skewness indicates an asymmetry extending toward the smaller qualitative scale points. Negative skewness indicates an asymmetry extending toward the high qualitative scale points. The kurtosis of measured quantities presents the flatness of the obtained results. Higher kurtosis values indicate a higher turbulence and variation among the obtained results. As the sustainability indicators produce a single value, the histogram, dispersion, kurtosis, and skewness analyses enable a deeper insight into the individual scores at the KPI level.

The analysis profile of the SoTE framework is summarized in Table 8. In Table 8, the mean, standard deviation, kurtosis, and skewness values are mapped onto qualitative scale points for assessment and interpretation. The overall mean of the institutional scores ( $\mu$ ) is mapped onto the original scale (*Nascent*, *Beginning*, *Developing*, *Competent*, *Accomplished*) using the midpoint of the ranges [6.25, 12.5], [12.5, 37.5], [37.5, 62.5], and [62.5, 87.5]; namely, 3.125, 25, 50, and 75. The standard deviation ( $\sigma$ ) from the mean ( $\mu$ ) is considered high if

the standard deviation is greater than 25. A standard deviation of 25 is the resultant of high variation in the scores among the scale points nascent, beginning, developing, competent, or accomplished. A positive kurtosis ( $\kappa$ ) means a large variation among the scores of individual *KPIs*, while a negative kurtosis means that the results are almost flat. A positive skewness ( $\varsigma$ ) means that the scores are individual *KPIs* skewed towards the high scale points, while a negative skewness indicates a skew in the results in the direction of low scale points.

In Table 9, we suggest the SoTE evaluation chart that produces the result regarding the sustainability of an institution or any of the indicators. The evaluation is done with respect to a reference institution with KPIs that are found to be Competent. Tuning is needed to the evaluation thresholds if the reference institution has KPI scores of accomplished or mixed values. The presented evaluation in Table 9 can be made more detailed where it relies on scores obtained from the complementary set of indicators. The same style of evaluation sheet can be used to focus on one criteria, KPM or a selection of KPIs.

## 6. Results and analysis

We conducted a pilot study at a private, non-profit, undergraduate higher education institution in the GCC region using a case-study methodology. Participants in the pilot study included faculty and staff, in regular and key administrative positions. Below are the procedures that were followed during the pilot study:

1. An initial test drive. The test drive included refining the plans, procedure, documents, forms, and ensuring artefacts balance.

**Table 8.** The SoTE analysis profile; the mean, standard deviation, kurtosis, skewness, and *SI* qualitative interpretation

Measurement	Scale				
	Nascent	Beginning	Developing	Competent	Accomplished
Mean ( $\mu$ )	$\mu < 9.375$	$9.375 \leq \mu < 25$	$25 \leq \mu < 50$	$50 \leq \mu < 75$	$\mu \geq 75$
Standard Deviation ( $\sigma$ )	Uniform: <i>Almost no variation in the obtained results</i>	Somewhat Disperse: <i>A little variation in the obtained results</i>	Disperse: <i>A considerable variation in the obtained results</i>	Highly Disperse: <i>A high variation in the obtained results</i>	
	$\sigma < 15$	$15 \leq \sigma < 20$	$20 \leq \sigma < 25$	$\sigma \geq 25$	
Kurtosis ( $\kappa$ )	Flat: <i>Almost no variation in the obtained results</i>	Normal: <i>Little variation in the obtained results</i>		Turbulent: <i>high variation in the obtained results</i>	
	$\kappa < 0$	$\kappa = 0$		$\kappa > 0$	
Skewness ( $\zeta$ )	Skewed towards low scores $\zeta < 0$		Normal with no skewness $\zeta = 0$		Skewed towards high scores $\zeta > 0$
<i>SI</i>	Sustainability is lower than the reference institution	Sustainability is somewhat lower than the reference institution	Sustainability is similar to the reference institution	Sustainability is higher than the reference institution	
	$SI < 0.7$	$0.7 \leq SI < 0.9$	$0.9 \leq SI < 1.1$	$SI \geq 1.1$	

**Table 9.** The SoTE Evaluation Chart. The evaluation is wrt to a reference institution with KPIs that are found to be competent

Scale Point: Attribute	Evaluation <i>The institution attains the following:</i>
<b>Sustainable:</b> <i>The institution is characterized with satisfactory <u>Improvability and Endurance</u></i>	<ul style="list-style-type: none"> <li>An <i>SI</i> score where the sustainability is <b>similar</b> to or <b>higher</b> than the reference institution</li> <li>The mean of scores (<math>\mu</math>) is at least <b>competent</b></li> <li>The standard deviation of the scores (<math>\sigma</math>) is no higher than <b>somewhat disperse</b></li> <li>The kurtosis of the scores (<math>\kappa</math>) is no higher than <b>normal</b></li> <li>The skewness of the scores (<math>\zeta</math>) is no higher than <b>normal</b></li> </ul>
<b>Partially Sustainable:</b> <i>The institution is characterized with either growing <u>Improvability or Endurance</u></i>	<ul style="list-style-type: none"> <li>An <i>SI</i> score where the sustainability is not less than <b>somewhat lower</b> than the reference institution</li> <li>The mean of scores (<math>\mu</math>) is at least <b>competent</b></li> <li>The standard deviation of the scores (<math>\sigma</math>) is no higher than <b>disperse</b></li> <li>The kurtosis of the scores (<math>\kappa</math>) is no higher than <b>normal</b></li> <li>The skewness of the scores (<math>\zeta</math>) is no higher than <b>normal</b></li> </ul>
<b>Barely Sustainable:</b> <i>The institution is characterized with growing <u>Improvability and Endurance</u></i>	<ul style="list-style-type: none"> <li>An <i>SI</i> score where the sustainability is <b>lower</b> than the reference institution</li> <li>The mean of scores (<math>\mu</math>) is at least <b>developing</b></li> <li>The standard deviation of the scores (<math>\sigma</math>) is no higher than <b>disperse</b></li> <li>For <b>any</b> kurtosis of the scores (<math>\kappa</math>)</li> <li>For <b>any</b> skewness of the scores (<math>\zeta</math>)</li> </ul>
<b>Unsustainable:</b> <i>The institution is characterized with either low <u>Improvability or Endurance</u></i>	<ul style="list-style-type: none"> <li>An <i>SI</i> score where the sustainability is <b>lower</b> than the reference institution</li> <li>The mean of scores (<math>\mu</math>) is <b>beginning</b> or <b>nascent</b></li> <li>For <b>any</b> standard deviation of the scores (<math>\sigma</math>)</li> <li>For <b>any</b> kurtosis of the scores (<math>\kappa</math>)</li> <li>For <b>any</b> skewness of the scores (<math>\zeta</math>)</li> </ul>

- Baseline perception data collection using a holistic version of the SoTE Rubric.
- Data collection using the analytic version of the SoTE Rubric.
- Rater calibration to insure basic reliability of rater scoring using the SoTE Rubric.
- Data collection using both the holistic and analytic versions of the SoTE Rubric.

The Institution's *SI*, using the analytic version of the SoTE Rubric, indicated *Barely Sustainable*. The Institution attained an *SI* of 0.5, which places it in a rank *lower than a reference institution* with a score of *Competent* in all KPIs. The Institution attained an overall score of *Developing* with *Somewhat Disperse results with a little variation*; the Mean ( $\mu$ ) is 37.43 and the Standard Deviation ( $\sigma$ ) is 19.47. The results



**Table 10.** The results for the set combined indicators, including *SI* as measured at the criterion level abbreviated as *CnSI* where *n* is the criterion number

Indicator	G $\mu$	$\mu$	Mapping	$\sigma$	$\kappa$	$\varsigma$	Evaluation
SI	0.5	37.43	Developing	19.47	0.18	0.7	Barely Sustainable
C1SI/ LGSI	0.43	35.56	Developing	20.74	0.18	0.7	Barely Sustainable
C2SI	0.41	33.33	Developing	24.63	-0.61	0.78	Barely Sustainable
C3SI	0.31	22.5	Beginning	13.69	-3.33	0.61	Unsustainable
C4SI	0.46	36.25	Developing	19.96	2.12	-0.47	Barely Sustainable
C5SI	0.29	20.83	Beginning	12.91	-1.88	0.97	Unsustainable
C6SI	0.69	38.82	Developing	17.94	-0.2	0.22	Barely Sustainable
C7SI	0.55	41.07	Developing	22.49	-1.82	-0.35	Barely Sustainable
C8SI	0.59	42.36	Developing	18.73	-1.1	-0.34	Barely Sustainable
C9SI	0.7	45	Developing	12.08	-1.22	1.04	Barely Sustainable
SLSI	0.38	30.98	Developing	22.88	-0.07	0.96	Barely Sustainable
RSI	0.34	26.17	Developing	16.17	-0.42	0.58	Barely Sustainable
TSI	0.57	40.68	Developing	17.95	-0.7	-0.04	Barely Sustainable
CESI	0.42	30.71	Developing	15.87	-0.44	0.14	Barely Sustainable
QSI	0.51	37.41	Developing	17.82	-0.93	-0.02	Barely Sustainable
FSI	0.5	36.67	Developing	18.95	-0.56	0.24	Barely Sustainable
ITSI	0.53	38.13	Developing	17.44	-0.85	-0.03	Barely Sustainable

were found to be flat and skewed towards the higher scale points with a negative Kurtosis ( $\kappa$ ) and a positive Skewness ( $\varsigma$ ).

*Barely Sustainable* was also the *SI* attained by the Institution when the holistic version of the SoTE Rubric was used: an *SI* of 0.44, which places it in a rank *lower than a reference institution* with a score of *Competent* in all KPIs. The institution attained an overall rank of *Developing* with *Somewhat Disperse results with a little variation*; the Mean ( $\mu$ ) is 32.17 and the Standard Deviation ( $\sigma$ ) is 17. The results were found to be flat and skewed towards the higher scale points with a negative Kurtosis ( $\kappa$ ) and a positive Skewness ( $\varsigma$ ).

The results from the study reflected a minimal difference in average scores after rater calibration. The difference in average scores before and after calibration was about 1% for both the analytic and holistic versions of the SoTE Rubric. The difference in average score between the analytic and holistic rubrics was found to be 5%. Calibration is important as it shows reliability between raters and serves as an indicator for validity of the measurement tool.

The results for the set of the combined indicators, including the sustainability measured at the criterion level, are presented in Table 10. The institution appears to be *Barely Sustainable* in all complementary indicators but *Criterion 3 Student Learning by Research Program* and *Criterion 5 Industry and Community Engagement*. Fig. 3 depicts the Geometric Mean, *Sustainability Indicator (SI)* and the mean ( $\mu$ ) of the combined indicators radar charts.

At the KPI level, all results are shown in the Table in Appendix B, for the analytic version of the SoTE Rubric and Table 11 for the holistic version of the SoTE Rubric. Using the analytic version of the SoTE Rubric, the institution attained the score *Accomplished* in KPIs 1.2.9.1, 2.5.1.5, and 6.5.3.1. The KPIs that are *Accomplished* are as follows:

- Develop faculty and staff (Under Criterion 1)
- Control plagiarism (Under Criterion 2)
- Provide, major-specific learning facilities (Under Criterion 6)

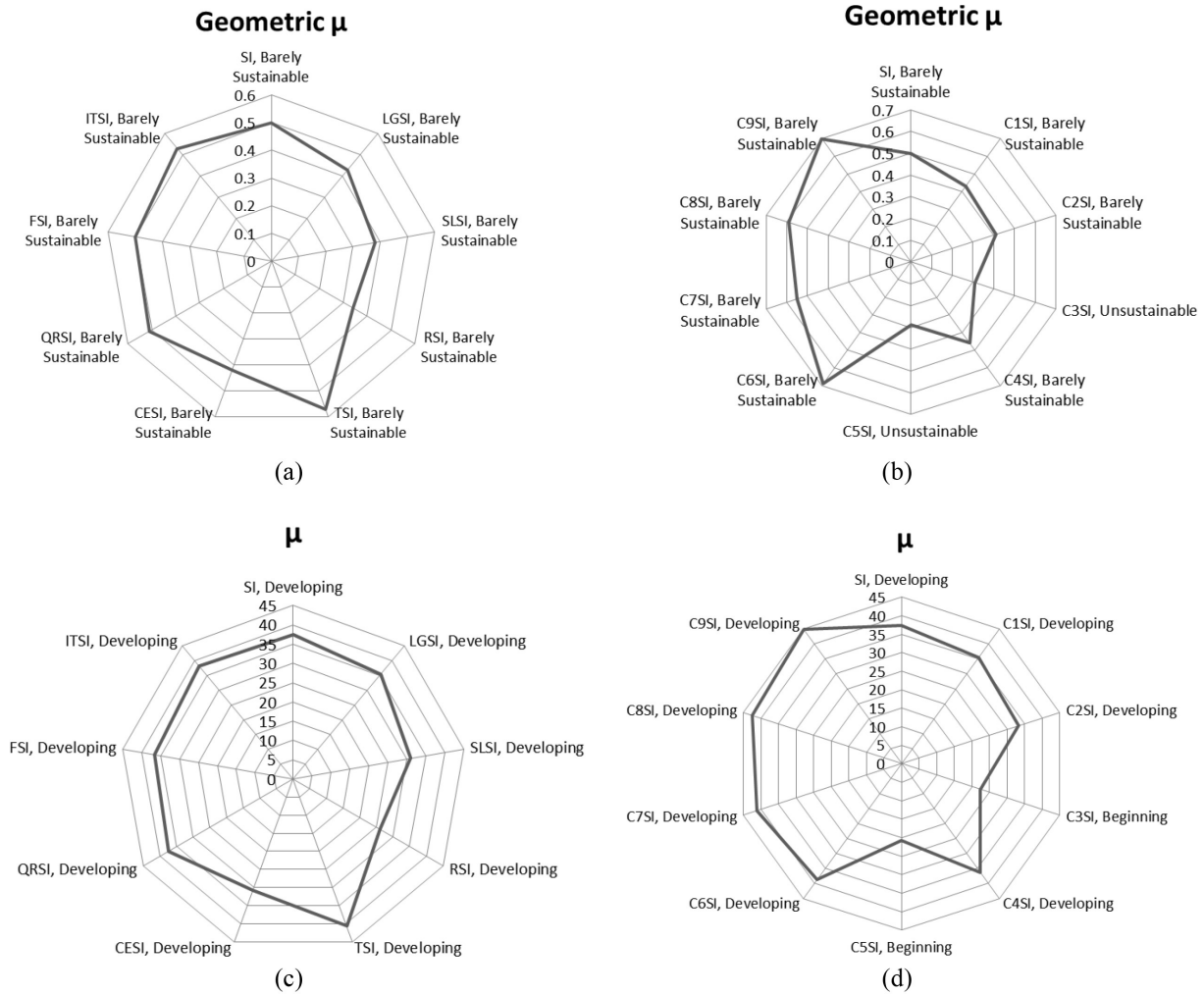
The institution attained the score of *Nascent* in KPIs 1.5.2.1 and 4.3.1, namely the following:

- Evaluates institutional effectiveness at the planning level (Under Criterion 1)
- Observe consultancy activities as professional development (Under Criterion 4)

In the holistic version of the SoTE Rubric, the institution attained no rating of *Accomplished*, while attaining *Nascent* in a single KPI; namely Student Research Support. The institution scored *Competent* in five KPIs, *Developing* in eighteen KPIs, and *Beginning* in ten. A histogram of the scores from the analytic version of the SoTE Rubric is shown in Fig. 4 The *Modes* of both the analytic and holistic version of the SoTE Rubric is *Developing*.

## 7. Evaluation and discussion

The proposed framework promotes the cultivation of the *SoTE* principles within higher education institutions. All constituents in an institution should aim to build a sustainable education that can improve and endure endlessly. The proposed framework shares several common challenges with the regular efforts of providing quality education. The challenges include the commitment, adequate investment, and support of the governing body of the institution to pursue and achieve *SoTE*. In addition, the challenges include the application of an educated change management that facilitates the cultivation of a new culture and deeply understand and control the change dynamics of the institution.



**Fig. 3.** Radar charts for (a) the geometric mean of the combined indicators' scores of Tables 6 and 7, (b) the geometric mean of the combined indicators' scores of Tables 10, (c) the mean of the combined indicators' scores of Tables 6 and 7, and (d) the mean of the combined indicators' scores of Table 10.

**Table 11.** KPIs (#) of the holistic version, results after calibration (AC), and mapping onto numerical point (N)

#	AC	N	#	AC	N
1.1	Beg.	12.5	5.1	Dev.	37.5
1.2	Dev.	37.5	5.2	Dev.	37.5
1.3	Dev.	37.5	6.1	Dev.	37.5
1.4	Dev.	37.5	6.2	Comp.	62.5
1.5	Beg.	12.5	6.3	Comp.	62.5
1.6	Beg.	12.5	6.4	Dev.	37.5
2.1	Comp.	62.5	6.5	Beg.	12.5
2.2	Comp.	62.5	6.6	Dev.	37.5
2.3	Dev.	37.5	7.1	Beg.	12.5
2.4	Dev.	37.5	7.2	Dev.	37.5
2.5	Dev.	37.5	7.3	Beg.	12.5
3.1	Dev.	37.5	7.4	Beg.	12.5
3.2	Nasc.	6.25	8.1	Dev.	37.5
4.1	Beg.	12.5	8.2	Dev.	37.5
4.2	Dev.	37.5	8.3	Comp.	62.5
4.3	Beg.	12.5	9.1	Dev.	37.5
4.4	Beg.	12.5	9.2	Dev.	37.5

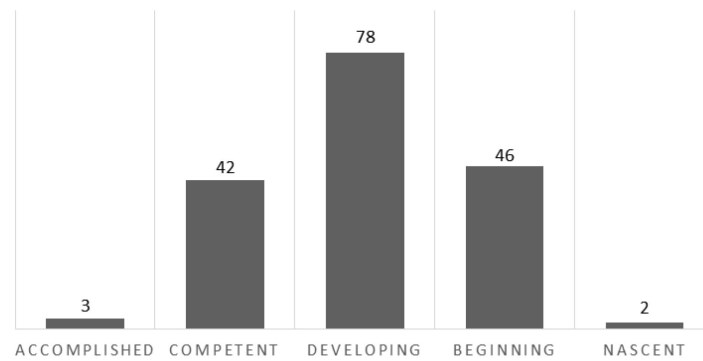


Fig. 4. The histogram of all KPIs of the analytic rubric showing the frequency per the attained rates.

Institutions must invest in the availability of an adequate infrastructure including Software tools to facilitate the deployment of the framework. Institutions should strive to ensure institutional effectiveness, disseminate SoTE awareness institution-wide, create a positive organizational climate, and cultivate relationships with external constituents.

For a successful deployment of the proposed framework, we reason about the frequency, of the assessment effort, to achieve the *SoTE (FAS)*. It is expected that the effort to achieve *SoTE* and the period of assessment should be well-specified per the institution's ability to function without reaching procrastination or breakdown. Procrastination comes from putting smaller effort than what it is necessary to make a successful change towards satisfactory *Improvability and Endurance* (See Table 1). Breakdown comes from putting bigger effort than that necessary to make a successful change towards satisfactory *Improvability and Endurance*. An example warning sign of breakdown is the inability of faculty and staff to fulfil requirements and the demonstration of resistance due to high workloads. We propose that a typical cycle to close the assessment loop is of three to six years due to the number of proposed *KPIs*. Single-year and seven-year cycles are considered critical and can lead to breakdown or procrastination.

Although the presented pilot study demonstrates the applicability of the proposed framework, limitations are noted. The presented work doesn't include checks that the measurement tool scores reliably deliver information about the *SoTE* that the institution provides. Reliability checks are needed including the finding of the correlation coefficient between the obtained measurement tool scores and scores from other established instruments that measure the same or similar criteria. Indeed, adopting *Sustainability* in quality assurance of technical education is a new concept and a pioneering investigation. Therefore, the identification of similar instruments for reliability checks and comparison purposes is

highly challenging. Indeed, it is intended to address research Question 2 (See Section 4) in a future phase of the investigation.

In this paper, we adopt and expand the definitions of sustainability and build on the findings from [21–23]. The work of Damaj et al. is the only closely related work in its attempt to present a formal framework that can be used to measure sustainability within tertiary engineering education. Our investigation, however, presents several additions that include the following:

- A new set of rubrics.
- An extended bouquet of combined indicators that can successfully rate, classify, and sort academic institutions per several indicators (See Tables 6 and 7).
- A set of statistical analysis parameters that include dispersion, histogram, kurtosis, and skewness of measured quantities.
- Analysis and evaluation charts that enable the draw of final conclusions on the sustainability of the assessed institutions.
- An extended calibration scheme for a set of 171 *KPIs* and the deployment of the complete framework in a single institution.
- A thorough analysis and evaluation of the framework and its deployment.

The comprehensiveness of the accreditation standards and quality assurance models inspires the presented *SoTE* framework [10, 30–36]. The Commission on Institutions of Higher Education (CIHE), a constituent element of the New England Association of Schools and Colleges (NEASC), is one of seven regional higher education accrediting bodies in the United States. NEASC is famous world-wide for its primary purpose of accrediting educational institutions. Per NEASC, the institution that meets the accreditation standards “. . . is achieving its purposes and has the ability to continue to achieve its purposes . . .” [32]. CIHE standards span a wide range of aspects that comprise mission and purposes; planning and evalua-

tion; organization and governance; the academic program; students; teaching, learning, and scholarship; institutional resources; educational effectiveness; and integrity, transparency, and public disclosure. ABET, the world's leading accrediting body of programs in technical education requires the demonstration of satisfaction of a set of general criteria [19]. ABET's general criteria for baccalaureate level programs comprise students, program educational objectives, student outcomes, continuous improvement, curriculum, faculty, facilities, and institutional support. Indeed, the proposed framework for *SoTE* covers both institutional and programmatic aspects.

The paper presents a new concept that defines the *Sustainability of Technical Education*. The results of the pilot study confirm that the framework describes the content and constructs that comprise sustainability of technical education in a higher education setting and measures the sustainability. The presented work aims to find the extent by which the implementation of the study contributes to demonstrating its value for the improvement of sustainability of education. In addition, the presented work answers to what extent does the implementation of the study assessment bring benefits to participating Institution.

The pilot study places the assessed institution in the rank of *Barely Sustainable* where it is characterized with growing *Improvability and Endurance*. The institution achieves an *SI* of 0.44 that places it in a rank *lower than a reference institution* with a score of *Competent* in all KPIs. The institution attained an overall rank of *Developing with Somewhat Disperse results with a little variation*; the Mean ( $\mu$ ) is 32.17 and the Standard Deviation ( $\sigma$ ) is 17. The results are found to be flat and skewed towards the higher scale points with a negative Kurtosis ( $\kappa$ ) and a positive Skewness ( $\varsigma$ ). The framework enabled the reasoning about more specific aspects at the levels of complementary indicators, criteria, and KPMs and KPIs.

As expected, the analytic version of the *SoTE* Rubric provided more detailed information of the measured indicators. In general, analytic rubrics provide more accurate measurement if raters are calibrated; it also provides a foundation for continuous improvement because the descriptors are more fine-grained, thus more actionable. Indeed, the holistic version is convenient and easier to deploy due to its reduced number of KPIs.

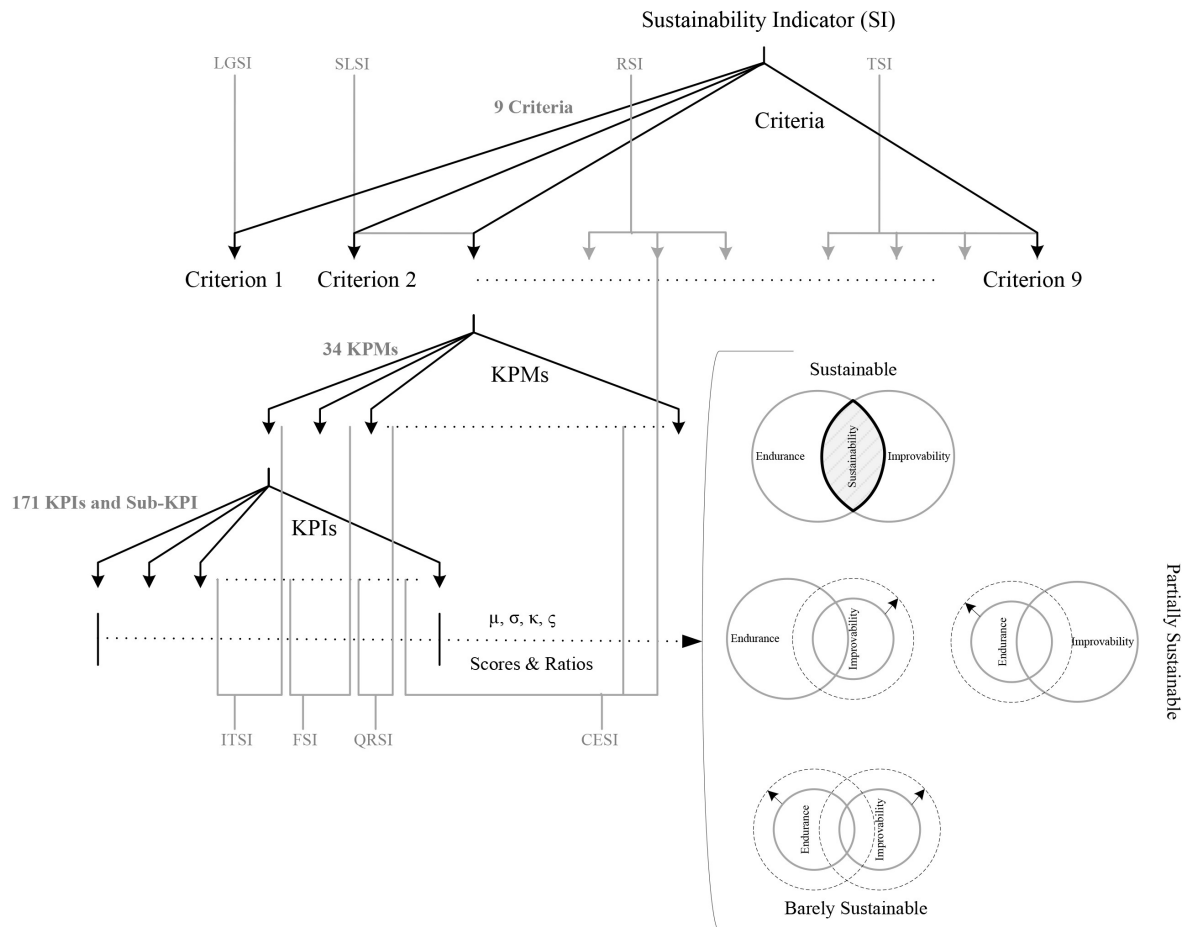
Several returns are noted for the *SoTE* measurement framework. Conceptually, it can be used to promote a multi-pronged approach to cultivating and maintaining quality in tertiary education. Because of its clear and flexible measurement framework and conceptual solidity, it can be relatively easily adopted, adapted and used by faculty, staff

and upper administration. Upon adoption by institutions, it could provide opportunities for inter- and intra-institutional measurements and cross-institution benchmarking that serve as an alternative to standard ranking measures. Because the *SoTE* was designed to be relevant, accurate and useful to users and stakeholders alike, the data generated is intended to be highly actionable, unlike many existing measures of quality.

Applying the framework to several institutions, in addition to making measurements from an exemplary reference institution, enriches the application and provides common grounds for mutual improvement among the participants. In response to the detailed level of KPIs and the required analysis and evaluation, a secure and visual online system is under development. The system enables the automatic generation of results, evaluation tables, and charts.

The conceptual base of the proposed framework promotes for a new perspective that serves quality education. The concept of sustainability is simple to comprehend and promote in technical education as it already has a wide-base of advocates. Moreover, the proposed framework formulates a novel methodology for measurement based on the modern concept of sustainability. At present, sustainability is widely observed as a student outcome in engineering programs including the current criteria of ABET's Engineering Accreditation Commission [29]. The proposed framework and its definition of *SoTE* captures the intended meaning of the term sustainability, in quality assurance context, with simplicity. The simplicity stems from the choice of the pillars, *Improvability and Endurance*, that naturally flow from term sustainability and the ease of their comprehension. Indeed, the framework adopts ANET's terminology [30] for its relevance to technical education, namely, engineering, engineering technology, computing, and applied sciences; this provides an increased applicability and alignment with programmatic review efforts.

The proposed framework adopts a hierarchal structure (See Fig. 5). The structure is built upon a large base of *KPIs* that are grouped under various *KPMs* and several criteria. The framework covers a widespread area of aspects and, therefore, it is horizontally wide as it spans across various institutional aspects. The *KPIs*, *sub-KPIs*, and rubrics enable vertically deep measurements of *SoTE* aspects that are more specific than *KPMs* and criteria. Furthermore, the framework is scalable and upgradable; supplementary criteria, measures, and/or indicators can be added without changing the statistical model. The proposed set of indicators and rubrics are extensive, comprehensive, and provide a rich menu of well-defined *KPIs*. Combined



**Fig. 5.** The measurement framework of *SoTE*, the *SI* that combines all *KPIs* (See Table in Appendix B), the set of combined indicators of Tables 6 and 7, and the analysis and evaluation options of Tables 8 and 9.

indicators can be tailored by amalgamating *KPIs*, *KPMs*, and/or criteria that can measure a desired property. Besides, the framework provides a clear evaluation chart that can be further customized. Moreover, the developed framework provides opportunities for inter-institutional measurements and cross-institution benchmarking. Academic institutions can be sorted and classified per the proposed indicators. Indeed, the developed framework enjoys the following characteristics of broader impact as it is:

- A new way of looking at quality assurance
- Developing a new culture
- A superset for accreditation
- A unified classification framework
- Applicable outside higher education
- Applicable outside education

## 8. Conclusions and future work

The paper presents a modern concept that defines *SoTE*. A structured measurement framework is refined from the pillars of Sustainability, namely,

*Improvability and Endurance*. The measurement framework has 9 criteria, 34 *KPMs*, and a total of 171 indicators with their analytic rubrics and a bouquet of statistical indicators. The framework adopts clear, easy-to-use, and customizable evaluation charts that aids the interpretation of results. The paper includes the results and analysis of a pilot study from a single institution using a case-study methodology. The results of the pilot study confirm that the framework describes the content and constructs that comprise sustainability of technical education in a higher education setting and measures the sustainability. The tool highlighted several points of strengths and weaknesses and identified opportunities of improvement at various levels of the framework structure. Work in progress aims to execute a multistage data collection procedure for a pilot study using a case-study methodology for one case that targets multiple institutions and for the complete set of criteria. Future work includes the development software tool that supports the deployment of the proposed measurement framework.

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## Appendix A. List of Acronyms

Acronym	Definition
$\kappa$	Kurtosis
$\mu$	Mean
$\varsigma$	Skewness
$\sigma$	Standard Deviation
CESI	Community Engagement Sustainability Indicator
CnSI	Criterion n Sustainability Indicator
CIHE	Commission on Institutions of Higher Education
ESD	Education for Sustainable Development
FAS	Frequency of the assessment effort to achieve SoTE
FSI	Facilities Sustainability Indicator
GM	Geometric Mean

Acronym	Definition
ITSI	Information Technology Sustainability Indicator
KPI	Key Performance Indicator
KPM	Key Performance Measure
LGSI	Leadership and Governance Sustainability Indicator
NEASC	New England Association of Schools and College
QRSI	Quality Review Sustainability Indicator
RSI	Research Sustainability Indicator
SI	Sustainability Indicator
SLSI	Student Learning Indicator
SoTE	Sustainability of Technical Education
TSI	Support Services Sustainability Indicator

## Appendix B. Supplementary Table

**Table.** KPI number (#) of the analytic version, results after calibration (AC), and mapping onto numerical point (N)

#	AC	N	#	AC	N	#	AC	N	#	AC	N
1.1.1.1	Dev.	37.5	2.5.1.4	Comp.	62.5	6.3.4.5	Dev.	37.5	8.3.1.3	Comp.	62.5
1.1.2.1	Beg.	12.5	2.5.1.5	Acc.	87.5	6.3.4.6	Dev.	37.5	8.3.1.4	Dev.	37.5
1.2.1.1	Dev.	37.5	3.1.1	Dev.	37.5	6.3.4.7	Dev.	37.5	8.3.1.5	Dev.	37.5
1.2.2.1	Beg.	12.5	3.1.2	Beg.	12.5	6.3.4.8	Dev.	37.5	8.3.1.6	Comp.	62.5
1.2.3.1	Beg.	12.5	3.1.3	Dev.	37.5	6.3.4.9	Dev.	37.5	8.3.1.7	Dev.	37.5
1.2.4.1	Beg.	12.5	3.1.4	Beg.	12.5	6.3.5.1	Dev.	37.5	8.3.1.8	Comp.	62.5
1.2.5.1	Dev.	37.5	3.2	Beg.	12.5	6.3.5.2	Dev.	37.5	8.3.1.9	Comp.	62.5
1.2.6.1	Dev.	37.5	4.1.1	Dev.	37.5	6.3.5.3	Dev.	37.5	8.3.1.10	Comp.	62.5
1.2.7.1	Comp.	62.5	4.1.2	Comp.	62.5	6.3.5.4	Beg.	12.5	8.3.1.11	Comp.	62.5
1.2.8.1	Beg.	12.5	4.2.1	Dev.	37.5	6.3.5.5	Beg.	12.5	8.3.1.12	Dev.	37.5
1.2.9.1	Acc.	87.5	4.3.1	Nasc.	6.25	6.3.5.6	Beg.	12.5	8.3.1.13	Beg.	12.5
1.2.10.1	Dev.	37.5	4.4.1	Dev.	37.5	6.3.5.7	Beg.	12.5	8.3.1.14	Dev.	37.5
1.2.11.1	Comp.	62.5	5.1.1.1	Beg.	12.5	6.3.5.8	Dev.	37.5	8.3.1.15	Dev.	37.5
1.2.12.1	Comp.	62.5	5.1.1.2	Beg.	12.5	6.3.5.9	Dev.	37.5	8.3.1.16	Dev.	37.5
1.2.13.1	Dev.	37.5	5.1.1.3	Beg.	12.5	6.3.5.10	Dev.	37.5	8.3.1.17	Dev.	37.5
1.2.14.1	Comp.	62.5	5.2.1.1	Dev.	37.5	6.3.5.11	Dev.	37.5	8.3.1.18	Beg.	12.5
1.2.15.1	Beg.	12.5	5.2.1.2	Beg.	12.5	6.3.6.1	Dev.	37.5	8.3.1.19	Beg.	12.5
1.3.1.1	Dev.	37.5	5.2.1.3	Dev.	37.5	6.3.6.2	Beg.	12.5	8.3.1.20	Beg.	12.5
1.3.2.1	Dev.	37.5	6.1.1.1	Comp.	62.5	6.3.6.3	Beg.	12.5	8.3.1.21	Dev.	37.5
1.3.3.1	Dev.	37.5	6.1.1.2	Dev.	37.5	6.3.6.4	Beg.	12.5	8.3.1.22	Beg.	12.5
1.4.1.1	Beg.	12.5	6.1.2.1	Dev.	37.5	6.4.1.1	Beg.	12.5	8.3.1.23	Comp.	62.5
1.4.1.2	Dev.	37.5	6.2.1.1	Comp.	62.5	6.4.2.1	Beg.	12.5	8.3.1.24	Comp.	62.5
1.4.1.3	Dev.	37.5	6.2.2.1	Dev.	37.5	6.4.3.1	Dev.	37.5	8.3.1.25	Comp.	62.5
1.4.1.4	Dev.	37.5	6.3.1.1	Beg.	12.5	6.5.1.1	Comp.	62.5	8.3.1.26	Dev.	37.5
1.5.1.1	Beg.	12.5	6.3.2.1	Comp.	62.5	6.5.2.1	Dev.	37.5	8.3.1.27	Beg.	12.5
1.5.2.1	Nasc.	6.25	6.3.2.2	Comp.	62.5	6.5.3.1	Acc.	87.5	8.3.1.28	Comp.	62.5
1.6.1.1	Beg.	12.5	6.3.2.3	Beg.	12.5	6.5.4.1	Dev.	37.5	8.3.1.29	Dev.	37.5
2.1.1.1	Comp.	62.5	6.3.2.4	Dev.	37.5	6.6.1.1	Dev.	37.5	8.3.1.30	Dev.	37.5
2.2.1.1	Comp.	62.5	6.3.2.5	Dev.	37.5	6.6.2.1	Beg.	12.5	8.3.1.31	Dev.	37.5
2.3.1.1	Dev.	37.5	6.3.2.6	Comp.	62.5	6.6.2.2	Dev.	37.5	8.3.1.32	Dev.	37.5
2.4.1.1	Dev.	37.5	6.3.2.7	Dev.	37.5	6.6.2.3	Dev.	37.5	8.3.2.1	Comp.	62.5
2.4.1.2	Beg.	12.5	6.3.2.8	Comp.	62.5	6.6.3.1	Dev.	37.5	8.3.3.1	Comp.	62.5
2.4.1.3	Beg.	12.5	6.3.3.1	Comp.	62.5	7.1.1.1	Beg.	12.5	9.1.1.1	Comp.	62.5
2.4.1.4	Beg.	12.5	6.3.3.2	Dev.	37.5	7.2.1.1	Beg.	12.5	9.1.1.2	Comp.	62.5
2.4.2.1	Dev.	37.5	6.3.3.3	Dev.	37.5	7.2.1.2	Dev.	37.5	9.1.1.3	Dev.	37.5
2.4.2.2	Beg.	12.5	6.3.3.4	Comp.	62.5	7.2.2.1	Comp.	62.5	9.1.1.4	Dev.	37.5
2.4.2.3	Beg.	12.5	6.3.3.5	Comp.	62.5	7.2.2.2	Dev.	37.5	9.1.2.1	Dev.	37.5
2.4.3.1	Comp.	62.5	6.3.3.6	Comp.	62.5	7.3.1.1	Comp.	62.5	9.1.3.1	Comp.	62.5
2.4.3.2	Beg.	12.5	6.3.3.7	Dev.	37.5	7.4.1.1	Comp.	62.5	9.2.1.1	Dev.	37.5
2.4.3.3	Dev.	37.5	6.3.4.1	Comp.	62.5	8.1.1.1	Dev.	37.5	9.2.2.1	Dev.	37.5
2.5.1.1	Beg.	12.5	6.3.4.2	Comp.	62.5	8.2.1.1	Beg.	12.5	9.2.2.2	Dev.	37.5
2.5.1.2	Beg.	12.5	6.3.4.3	Dev.	37.5	8.3.1.1	Comp.	62.5	9.2.3.1	Dev.	37.5
2.5.1.3	Beg.	12.5	6.3.4.4	Dev.	37.5	8.3.1.2	Comp.	62.5			

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