The differing approaches to sustainability between practising and academic Quantity Surveyors

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ABSTRACT

Most interpretations of sustainability in construction stem from the definition of sustainable development, which is a development that meets the needs of the present without compromising the future generation's needs. Various research and sustainability studies within the construction industry focus on finding economical, social, and environmental balance. Construction professionals, such as Quantity Surveyors, begin their learning journey by studying in colleges and progressing to higher education. As the construction industry evolves through modern techniques, higher education institutions must also follow suit.

These modern techniques have arisen due to the shift of ethos towards sustainability. Without the higher education institutions including this new knowledge in their curriculum, future professionals will not be equipped with the correct skills. Few research have been conducted in relation to students' views on sustainability. Although such research is at a minute level, thus the converse side of the argument is how professional Quantity Surveyors view these topics on sustainability and whether they implement them in their daily duties. Hence, the research explores the differences in understanding between practicing and academic Quantity Surveyors on sustainable development in their various professional duties.

The research was conducted using questionnaires that was distributed using survey monkey. The results were analysed through Spearman and ANOVA statistical tests to check their correlations. The study found a difference in the knowledge acquired by practicing and academic Quantity Surveyors. This finding conveys the importance of sustainability knowledge and how it is fundamental in achieving the UN sustainable goals and using such knowledge in practice.

KEYWORDS: Construction, Education, Quantity Surveyor, Sustainability

INTRODUCTION

Sustainability and construction have been discussed and interpreted in many forms over recent years and thoroughly developed in the modern day (Ekundayo *et al.*, 2011). No matter how sustainability is described within construction, it always comes back to the three core principles of environment, economy, and social (RICS, 2007). Currently, there is a massive skill gap between Quantity Surveyors in education or qualified Qunaity Surveyors, and the new skill set required for achieving a sustainable industry and value for money (Ekundayo *et al.,* 2011). The Quantity Surveyors' role has evolved from their first recorded use of calculating the cost of measured quantities compared to paying craftsmen the usual hourly rate for London's rebuilds after the Great Fire of London in 1666 (Ashworth *et al.*, 2013). The ever-present ethos of minimising cost will never disappear; however, the term cost has developed into the more meaningful value (Cartlidge, 2017). Value allows clients, customers, and users to incorporate the three pillars of sustainability into their projects. Within the construction industry, the procurement responsibility demonstrates why Quantity Surveyors are so crucial in ensuring sustainable procurement of buildings and services.

Education is an effective means of utilising new ideas or activities of a profession (Ekundayo, *et al.*, 2011). Sustainability is an evolving area; therefore, it poses the question of whether Quantity Surveyors have been educated to incorporate up-to-date sustainability developments within their work (Perera & Pearson, 2011). Currently, universities have identified some topics within sustainability that are not included in the syllabus (Ekundayo *et al.,* 2011). By including all topics surrounding sustainability within the curriculum, sustainability can begin its journey of embedment into the construction industry (HEFCE, 2010). Research has stated that students starting their higher education have low knowledge of sustainability, hence focusing on this topic will raise awareness and knowledge (Ekundayo *et al.,* 2011). Sustainability is becoming a vital factor to incorporate into all aspects of construction. Without the basic understanding and constant practice, one cannot keep up to date with the advances in sustainable development.

Many university courses continue to incorporate sustainability into their programme. This leave experienced professionals who have completed university study and are currently practicing in the hands of their companies and professional bodies within the construction industry having to educate these professionals, so their knowledge is up to date with government targets (Ekundayo *et al.,* 2011). The adaptability of these cost-driven professionals plays a vital role in driving away from cost ethos to a value-driven ethos that enhances sustainability (Ekundayo *et al.*, 2017). Since not every Quantity Surveyor is a member of a professional body, all parties need to organise Continuous Professional Development CPD programmes for their staff. Often construction professionals' knowledge on sustainability comes from CPD or self-learning (Owen, 2005). The report suggests only 36% of Quantity Surveyors are Chartered, while the RICS suggests this is around 50%. Hence further learning around sustainability would have to be self or company taught (Cartlidge, 2017). Thus, the need to explore the knowledge level of practicing and academic Quantity Surveyors on sustainability in the discharge of their professional responsibilities.

CONSTRUCTION AND SUSTAINABLE DEVELOPMENT

Climate change is a global, sustained shift in the world's weather patterns and temperatures due to the quantity of CO^2 in the atmosphere (Elliott, 2012). The constant melting of the glaciers poses a real threat to the planet, thus triggering an immediate plan to combat climate change (Pettenger, 2016). The Stern Review confirmed this problem and emphasised the need for urgent action. The main factor causing climate change is CO^2 emissions from human activity; this further identifies sustainability as one of the main solutions (Stern, 2006). Without change, finite natural resources would disappear, current and future needs would not be met (Ekundayo *et al.*, 2017). Hurlimann *et al.* (2018) identified the following barriers: resources issues (lack of time, money, and technology), institutional issues (governance and policy), psychosocial issues (cultural barriers, industry perceptions of client and public opinion) in the adaptation of sustainability into the construction industry. Government interventions include issuing of Industrial Strategy White Paper for new buildings to have zero CO^2 emission during the construction phase and halve the energy usage after construction by 2030 (Elliott, 2012).

The motivation for change within the construction industry is the monetary value associated with the industry. The construction sector is within the top five sectors for GDP in every country (Mosaku *et al.*, 2006). Isa *et al.* (2013) stated that the monetary value of the construction industry allows for a vast developmental opportunity, enhancing the cooperation of all the clients, whether government or private. Conversely, increasing the value of a contract or end price of a product allows new-build companies to take full advantage of an increased profit margin rather than concentrating on delivering better quality. Brundtland's (1987) research reveals that the construction industry views reducing waste and carbon as a high extra financial cost that has little benefit. Three hundred and eighty million tonnes of construction materials are utilised for construction actives across the UK every year. Osmani (2012) further this point, more than one hundred million tonnes of waste are produced by the construction industry, roughly thirteen million tonnes are unused materials. The failure to stop this unused resource from being wasted proves the inefficiency within the construction industry. The construction industry structure is fragmented, neglecting, minimising communication and collaboration between competitors (Alwan *et al.*, 2017). This leads to SME's having huge responsibilities regarding sustainability, and they must think of the overall bigger picture rather than just financial opportunities.

The fight against climate change is directly linked to sustainable development, which comes from the built environment being designed, constructed, and maintained correctly (Elliott, 2012). The client's ethos of minimising short-term project costs needs to be replaced with consideration for the long-term whole life costs. Cartlidge (2017) argued that an increase in initial cost would be linked to more sustainable methods. Raynsford (1999) concluded that this would allow the construction industry to quantify and measure sustainable targets by tracking different companies' progress. Incorporating a Quantity Surveyor at the earliest opportunity enables an estimate to cost to be actualised for the various environmental impacts surrounding the life cycle cost of the project for the different methods (Cartlidge, 2017).

QUANTITY SURVEYORS AND SUSTAINABLE DEVELOPMENT

The construction industry recognised that sustainable development has many benefits currently not being utilised (Cartlidge, 2017). Construction activities have evolved because of technological advances, and all construction professionals have an essential role in such substantial changes (Chamikara *et al.*, 2020). Quantity Surveyors with innovative new technologies like Building Information Model (BIM) would be efficient with their vital experience and knowledge surrounding cost; their main role will be to evaluate the economic side of the sustainability model. This role has adapted to modern times to become more diverse than advising about cost and cost management. Cartlidge (2017) argued that Quantity

Surveyors could add value to a project by advising on the best value of a construction process or procedure by utilising their procurement and contractual/legal experience to add value in terms of social and environmental rather than minimising cost. (Chamikara *et al.,* 2020).

The construction industry accounts for 25-30% of all EU waste, with many of this waste currently containing different materials that can be recycled and reused (The European Commission, 2016). The barrier to recycling this material is cost, or more directly, the cost to the project sometimes, and clients do not have a budget for the extra cost (Cartlidge, 2017). However, with specification change, Quantity Surveyors can include waste recycling, reusing, or repurposing in the tender documentation, allowing disposal cost to be reduced while reducing the overall construction waste (Seidu *et al.,* 2019). Quantity Surveyors' main goal is to assist with delivering a project on time and within budget. However, the government has placed emphasis on turning the industry greener with a new strategy in place such as; Construction 2025 and more comprehensive legislation like EU Directive 2002/91/EU for EPCs and DECs in support of greener development (Cartlidge, 2017). Enhancing the built environment includes eliminating inefficiencies for all phases and aspects of construction works by accurately reporting the advantages and disadvantages of different construction methods, materials, and costs to better understand efficiency (Ekundayo *et al.,* 2011). Comparing usage against output and cost provides a definite answer for the best option during the pre and post-construction phase (Cartlidge, 2017). Decision making is a crucial skill for Quantity Surveyors. Failure to act in the best interest of the construction industry due to professional interest leaves the built environment unprotected. Hence exceeding the industry's disciplinary boundaries for self-gain is detrimental to the protection of the built environment (Olatunji *et al.,* 2010). All this value is expantiated in the following subsections.

Environmental Impact Assessments (EIA)

Exploring environmental impact assessments of all the available construction options will produce efficiencies by measuring and analysing with different criteria during pre and post-construction effects with direct or indirect impact on the environment Tam et al. (2004). A thorough environmental impact assessment will produce reliable results so the best environmentally friendly option can be selected for the proposed budget (Wathey & O'Reilly, 2000). The inclusion of BREEAM will give the client the visibility, knowledge, techniques, and professional identities of all environmental concerns, which may not have been within their remit or vision initially (Schweber, 2013). Extra measures above and beyond the original BREEAM plan can then be actualised (Atkinson, 2009). By instilling these voluntary initiatives as regulations, the construction industry will strive towards total green construction (Tan *et al.,* 2011). Many construction companies have a strategic plan to be at the forefront of innovation for public relations, this is by introducing new greener and more efficient construction methods or processes (González-Benito *et al.,* 2011).

The carbon agenda is aimed at reducing the amount of carbon we use (Boardman, 2007) through a reduction in fossil fuel by 80% in 2020 and 90% by 2025 (Kibert, 2016), while the UK is committed to reducing 80% of CO^2 emissions by 2050 (Cambridge University Press, 2014). The construction industry produces 2.76% of the UK's total CO^2, while the final use of buildings produces a significant 33.52% of the UK's total CO^2 emissions (Statista, 2019). The Quantity Surveyor is better positioned to advise clients on alternatives to material usage or methods of recycling, reusing, or repurposing construction waste through carbon calculation

(Owen, 2005). They could advise on life cycle costing of alternative material and modification of carbon footprint into cost plan in advising the clients not only on the project cost but including carbon efficiency property of alternative materials (Seidu *et al.*, 2019). The use of locally procured and ethically sourced materials, plants, and labour through responsible and sustainable methods will help mitigate risks, reduce operating costs, and protect brand reputation (Glass, 2011). Further, it provides a sustainable assurance that a primary resource does not dry up (Khiyon, 2017). Going above and beyond this requirement demonstrates that one has recognised the broader responsibility to operate for the greater good rather than a simple profit maximising business (Ibrahim & Shakantu, 2017). Changing this profit maximising stigma related to the construction industry, with Quantity Surveyors, is one of the main drives to ensure sustainability. Increasing health and safety awareness is linked to increased efficiency by decreasing the time lost due to injuries (Cartlidge, 2017). Implementing the new CDM regulations is the clients' responsibility to protect all workers and the public when conducting their construction works (Summerhayes, 2016). Although the construction industry has evolved over the past 30 years, it still produces inefficiencies, such as roughly 1.7 million lost working days, due to injury or ill health (Cartlidge, 2017). Much is still expected from the industry to avoid time and cost overruns that can be incurred from inadequate management of health and safety in the project site.

Cost Benefit Analysis (CBA)

The use of social life cycle assessments on construction projects to evaluate each stage of the project helps to perceive if we can effectively reuse, recycle or re-invigorate an existing product for different use. This drives efficiencies and minimises adverse environmental effects, which in the long run reduces costs (Balasbaneh *et al.*, 2018). Using cost-benefit analysis (CBA) can aid decision-making and encourage more sustainable methods and materials (Ekundayo *et al.*, 2017) by analysing different tenders or proposals to decide if certain benefits can be realised and by what margin against the cost (Ekundayo *et al.*, 2011). Hong *et al.* (2018) showed that breaking this down into smaller budget elements of a project will show where each budget can benefit from more sustainable and cost-efficient methods. This sustainable cost comparison or carbon modification in cost plan can decrease cost and increase a sustainable footprint for a client or increase profit while increasing reputation for a contractor (Ekundayo *et al.*, 2011; Hong *et al.*, 2018; Seidu *et al.*, 2019). The use of different materials produces varied costs and sustainable impacts (Suryawanshi *et al.*, 2012). Sandanayake *et al.* (2018) show that all methods, materials, procedures, and processes need to be captured within the cost benefit analysis to ensure they utilise the most cost and environmentally efficient ways to execute the projects. It is important for clients to achieve value for money while minimising the adverse effects to the environment. The optimum value for money can only be accomplished, if all construction professionals have communicated and worked efficiently to complete the project (Chamikara *et al.*, 2020). Ashworth *et al.* (2013) noted that minimising cost in exchange for quality is not value for money, but effective collaboration between design, engineering, and cost to find the best solution for all three is how value for money is achieved.

Professional Competency

The duty of care to the built environment is not taught in the construction industry but within the professional bodies. Approximately 64% of all Quantity Surveyors who are not Chartered

(Cartlidge, 2017) continue to receive a different form of training that is company-specific (Ekundayo *et al.*, 2017). This causes lack of knowledge in sustainability, which has contributed to the lack of practice of such knowledge, while smaller companies do not have the time or money to invest in development or training. Investment in training and the development of their staff will help smaller companies to promote their value by bolstering the quantity of chartered/educated professionals in their organisation (Cartlidge, 2017).

Life Cycle Costing (LCC)

Quantity Surveyors must measure the life cycle cost of projects by estimating projects' cost from the procurement of the resources to when it will be recycled, reused, or demolished (Chiurugwi *et al.*, 2010). This decreases the adverse environmental impact while also providing monetarily savings throughout the life cycle of the building. Seah (2009) argues that one possible method of doing this is keeping up to date with modern green technologies through industrial practice or professional education. Without the construction industry being educated about these new green technologies, a Quantity Surveyor cannot incorporate these vital technologies to decrease adverse environmental impact (Seah, 2009). Pukšec *et al.* (2019) allow us to understand that the failure to include renewable energy technologies exposes the end product to outdated and potential future non-compliant elements. The life cycle process will enable a Quantity Surveyor to understand and predict the cost savings through material and methodical adjustments (Seidu *et al.*, 2019).

Professionalism

According to Chel and Kaushik (2018), a better and greener reputation within the industry will improve professionalism and professional creditability with clients. Seah (2009) argues that one possible method of keeping up to date with modern green technologies is through industry practice or professional education. This will, in turn, benefit the client through efficiency and effectiveness of the contractor and contractor through monetary or financial driven in the form of gain share, programme, and technical incentive (Rose & Manley, 2011). Olubunmi *et al.* (2016) argue that financial gain can be detrimental to achieving full sustainability as some companies' ethos is only driven by profit maximisation. Olubunmi *et al.* (2016) and Rose and Manley (2011) assert that client motivation can turn into a project motivation driver that creates the necessary drive to contractors. The RICS (2015) and Seidu *et al.* (2020) conclude that innovative technology like Building Information Modeling, Common Big Data, E-Procurement can complement the evolving roles of Quantity Surveyors in improving sustainable development to help achieve sustainable goals.

METHODOLOGY

This study is based on the primary data collected through a questionnaire designed. The questions are based on the research framework with supporting evidence in the literature review. For proven and reliable results, the questionnaire will be interpreted/modified according to Ekundayo *et al.* (2017) study to suit this study's aim. The configuration of this questionnaire is adapted from previous research. Two questionnaires for the construction industry and higher education were structured to collect data from a concise sample. These include practicing Quantity Surveyors and Chartered Quantity Surveyors within the construction industry and academic Quantity Surveyors in higher education institutions. Both questionnaires contain similar information from the sustainability framework, such as value for money, life cycle costing, and procurement. The only difference was the direction of the question.

This study adopts a deductive approach which allows the results to be expressed as a series of statistics that can be analysed and compared to disagree or back up previous Secondary research (Bryman, 2012). The questionnaires were created and distributed via survey monkey. An initial questionnaire was developed and tested against a small sample to check for amendments and improvements. This was done to ensure that the questionnaire was effective through the trial and error method. Overall, the two questionnaires had 46 respondents from a sample size of 60. These results were analysed using Spearman and ANOVA statistical tests to check for correlations.

FINDINGS AND DISCUSSION

Statistical analysis

One way of testing quantitative data is statistical testing. Statistical testing allows data to be tested against different confidence levels (Bryman, 2012), finding the correct level of rejection or acceptance against a hypothesis. By weighting the answers to each sustainability question, "what is your knowledge of each sustainability topic?" as shown in Figure 1.1, we can directly compare the higher education and construction industry results. A detailed methodology of how the responses were weighted is provided.

Table 1: x-values and explanation of sum of x values

	x_0	x_1	x_2	x_3	x_4	$\sum_{k=0}^{4}(x_k)$	
What is your knowledge of each sustainability topic?	No Knowledge	Heard of but cannot explain	Heard of and can explain	Good understanding	Complete understanding	Total no. of responses	Weighted Average
Example: Sustainable development & construction	0	8	14	16	2	40	57.50

Table 2: y-values and explanation of y values

y-Value	Responses	Weight
y_0	No Knowledge	0

y_1	Heard of but cannot explain	25
y_2	Heard of and can explain	50
y_3	good understanding	75
y_4	Complete understanding	100

x_k and y_k have been defined as per the values in Tables 1 and 2 respectively, the formulae used to generate the weighted answers is:

$$\frac{\sum_{k=0}^{4}(x_k \times y_k)}{\sum_{k=0}^{4}(x_k)} = \frac{(x_0 \times y_0)+(x_1 \times y_1)+(x_2 \times y_2)+(x_3 \times y_3)+(x_4 \times y_4)}{(x_0+x_1+x_2+x_3+x_4)}$$

For example, using Tables 1 and 2:

$$\frac{\sum_{k=0}^{4}(x_k \times y_k)}{\sum_{k=0}^{4}(x_k)} = \frac{(0 \times 0)+(8 \times 25)+(14 \times 50)+(16 \times 75)+(2 \times 100)}{(0+8+14+16+2)}$$

$$= \frac{2{,}300}{40}$$

$$= 57.5$$

The results show how Quantity Surveyors in higher institutions have more in-depth knowledge than those within the construction industry for 18 of the 23 sustainability topics. Of the five that practitioners have more in-depth knowledge than the higher education institutions, they are all directly linked to cost or health and safety. This reflects that practitioners do not intentionally influence their commercial team to prioritise cost over sustainability. This is further reflected in this question: “which sustainability topics do you use in your day-to-day Quantity Surveying duties?”.

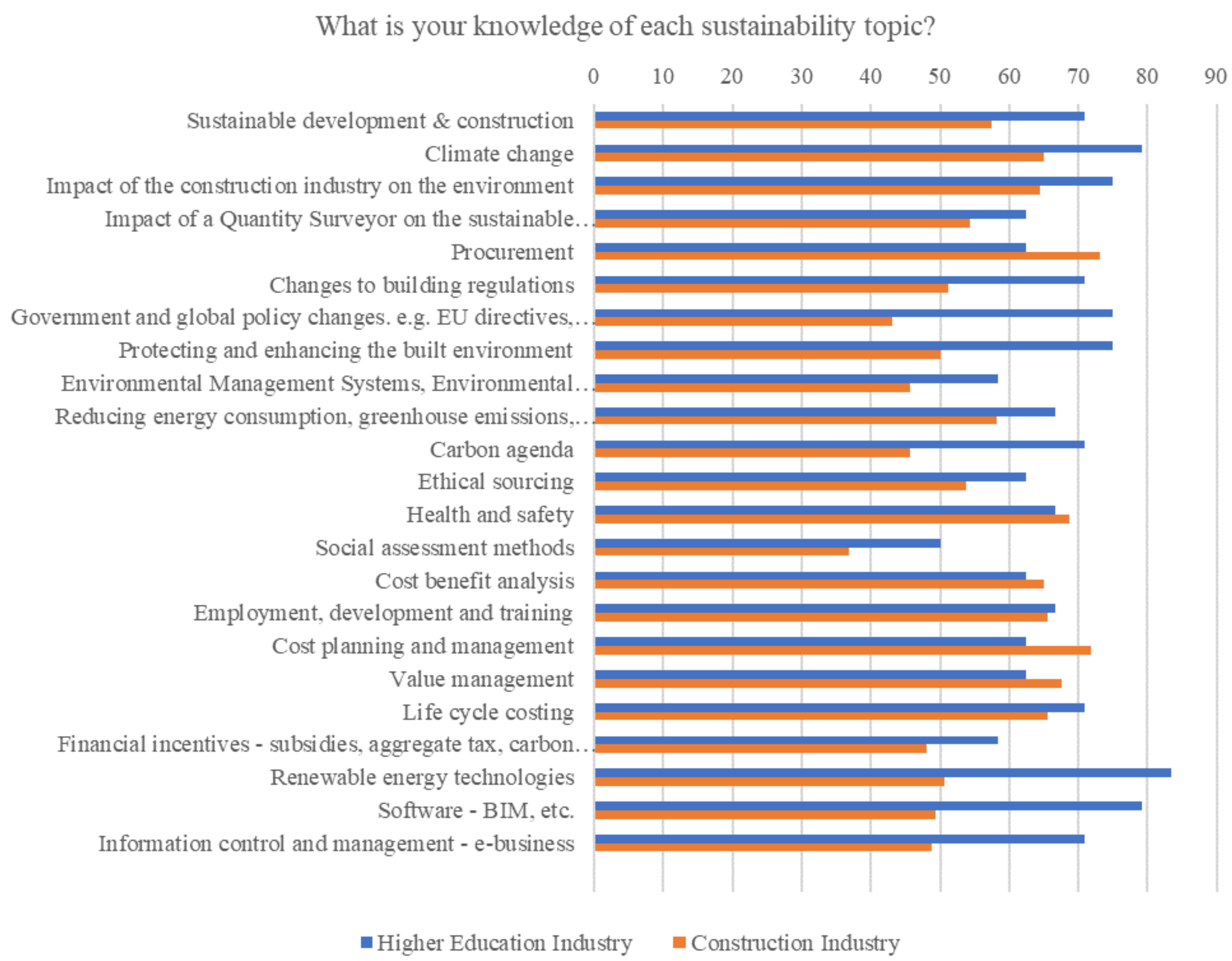

Figure 1: Graphical membership function of the three fuzzy sets (Sutrisna *et al,* 2004)

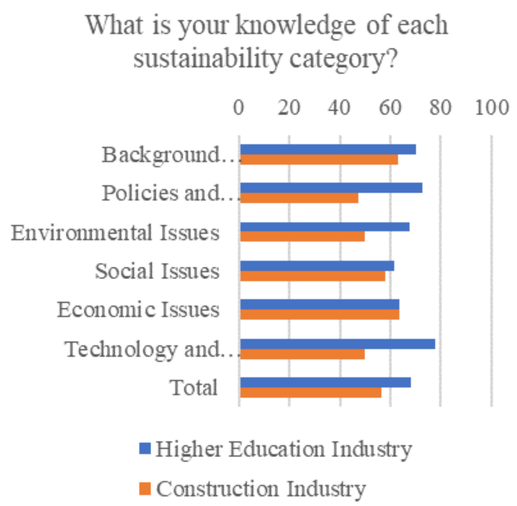

Figure 2: Knowledge of each sustainability topic

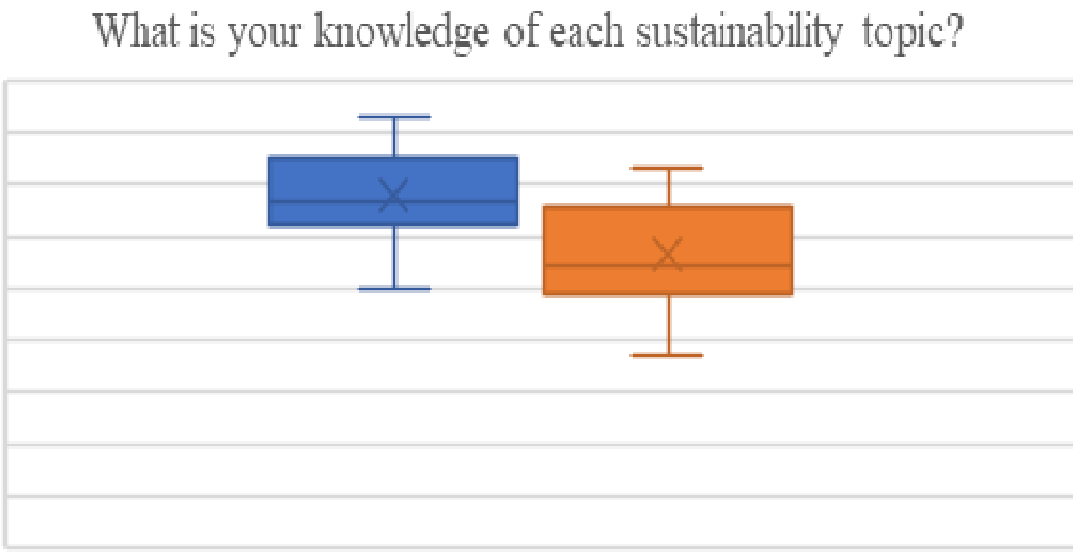

Figure 3: Box plot of data from: What is your knowledge of each sustainability topic?

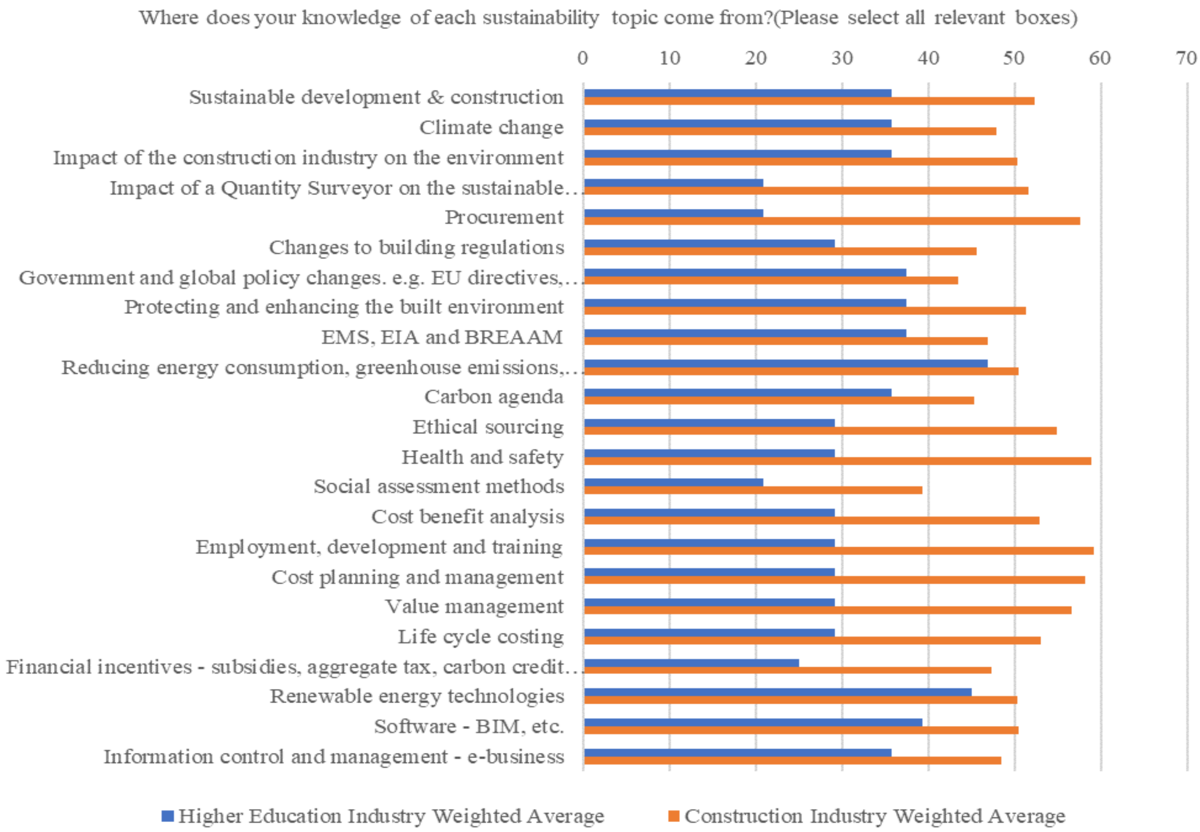

Figure 4: Knowledge of each sustainability topic (Higher Education Institution v Construction Industry)

Both box plots for the Higher Education Institution and Construction Industry read similar to normal distribution, the median is close to the centre, lower and upper quartile are similar distances from the centre and the maximum and minimum number are similar distances from the lower and upper quartile. Demonstrates good data for reliable statistics.

Data for the question 'Where does your knowledge of each sustainability topic come from? (Please select all relevant boxes)', is ranked towards the weight rather than 100.

The Higher Education Institution is closest to 25, hence the main source of their knowledge is education. The Construction Industry is closest to 50, hence their main source of knowledge is education, self-taught and company taught.

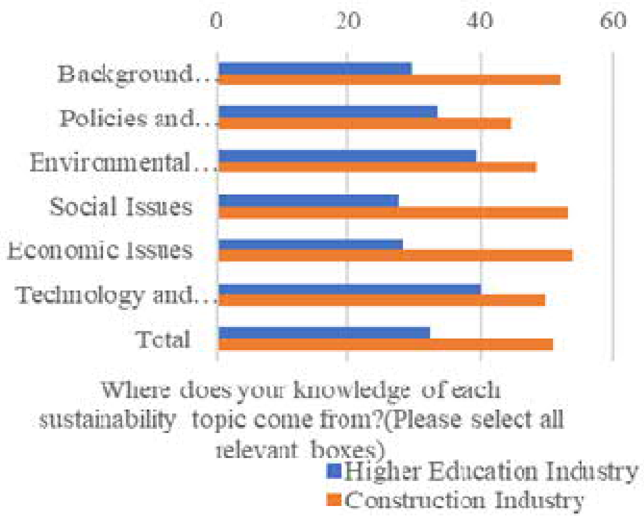

Figure 5: Knowledge of each sustainability topic (Higher Education Institution v Construction Industry comparison)

Table 3: Weight for each answer

Answers	Weight
No Knowledge	0
Education	25
Self taught	50
Company taught	75
Professional Body	100

Spearman Correlation

This section includes a summary of the data required to calculate spearman correlation (ρ) to four significant figures. All data for these calculations are in Appendix 1. For the construction industry, the utilisation of the spearman correlation is to see if there is a direct link between the amount of knowledge acquired against applying the knowledge in practice (Bryman, 2012). For this question, “which sustainability topics do you use in your day-to-day Quantity Surveying duties?” The same formula was utilised to generate the weighted answer with the ‘y’ variable being defined in Table 3.

Table 3: y values and explanation of y values

Y VALUE	ANSWERS	WEIGHT
y_0	Never	0
y_1	Three to four times a year	25
y_2	Once a month	50
y_3	Once a week	75
y_4	Daily	100

Table 4: Spearman correlation data set 1

$\sum d^2$	416
Degrees of Freedom (df)	21
n	23
n^3	12167

Using the information in Tables 3 and 4 regarding the weighted answers and associated ranks of these answers to the question, “What is your knowledge of each sustainability topic?” and “which sustainability topics do you use in your day to day Quantity Surveying duties?” this information can be analysed using the spearman correlation formulae below.

$$\rho = 1 - \frac{6\sum d^2}{(n^3 - n)}$$

$$= 1 - \frac{6 \times 416}{(12167 - 23)} = 0.7945$$

The Spearman correlation coefficient for the ranks between knowledge and use of the different sustainability topics is ρ = 0.7945. Figure 6 demonstrates the Spearman correlation with a red star to show where 0.7945 is. Figure 6 clearly shows a strong positive correlation between the knowledge and use of the sustainability topics; hence the more knowledge you have, the more you will use it in your day-to-day activities. To scrutinise this further, a one-tail test for Spearman correlation with 21d.f for a significant value of 0.002 ρ would have to exceed 0.647. Thus the correlation is significant.

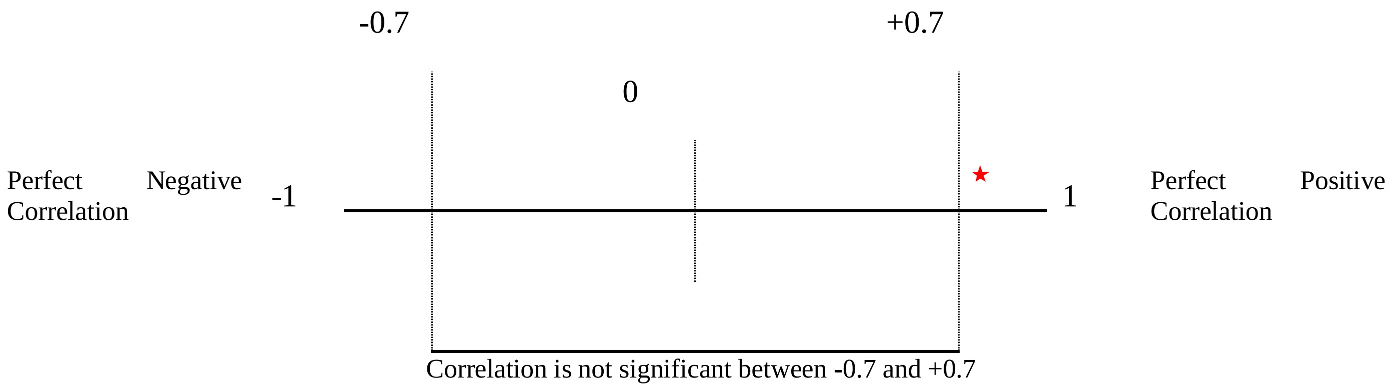

Figure 6: Spearman correlation, visual representation

For both the Higher Education Institution and the construction industry the Spearman test can define the correlation between these two questions, “What is your knowledge of each sustainability topic?” and “where does your knowledge of each sustainability topic come from?”. This will enable an understanding of where, or if, any similarities lie. For the construction industry, the results are summarised in :

Table 5: Spearman correlation data set 2

$\sum d^2$	312
Degrees of Freedom (df)	21
n	23
n^3	12167

$$\rho = 1 - \frac{6\sum d^2}{(n^3 - n)}$$

$$= 1 - \frac{6 \times 312}{(12167 - 23)}$$

$$= 0.8458$$

For Higher Education Institution the results are shown below:

Table 6: Spearman correlation data set 3

$\sum d^2$	640
Degrees of Freedom (df)	21
n	23
n^3	12167

$$\rho = 1 - \frac{6\sum d^2}{(n^3 - n)}$$

$$= 1 - \frac{6 \times 640}{(12167 - 23)}$$

$$= 0.6838$$

Although both results show a strong positive correlation between their knowledge and where it originates, they differ by over 15%, highlighting that the true measure of similarity cannot be defined or confirmed. For further scrutiny of correlation, we can test the sustainable knowledge and source of such knowledge of the Construction Industry against the Higher Education Institution.

For the construction industry and the higher education institutions knowledge', the results are:

Table 7 - Spearman correlation data set 4

$\sum d^2$	2400
Degrees of Freedom (df)	21
n	23
n^3	12167

$$\rho = 1 - \frac{6\sum d^2}{(n^3 - n)}$$

$$= 1 - \frac{6 \times 2400}{(12167 - 23)}$$

$$= -0.1858$$

For the 'source of such knowledge' the results are:

Table 1.8 - Spearman correlation data set 5

$\sum d^2$	2638
Degrees of Freedom (df)	21
n	23
n^3	12167

$$\rho = 1 - \frac{6\sum d^2}{(n^3 - n)}$$

$$= 1 - \frac{6 \times 2638}{(12167 - 23)}$$

$$= -0.3034$$

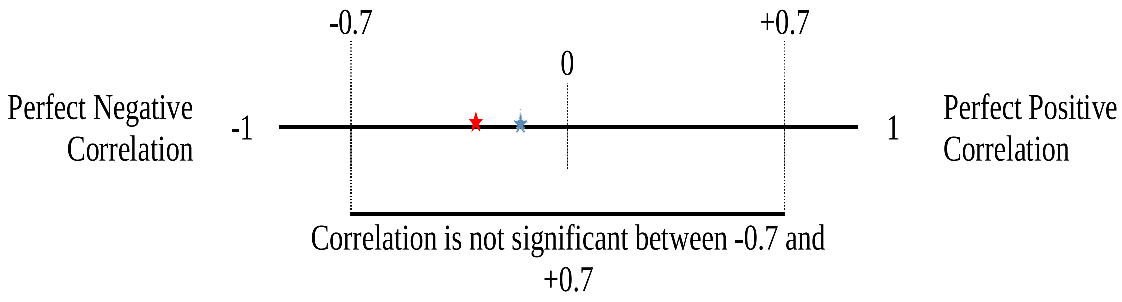

Figure 8: Spearman correlation, visual representation

A spearman correlation of -0.1858 and -0.3034 shows no correlation between 'the knowledge' and 'source of knowledge' between the construction industry and the higher education institutions, as shown in Figure 1.8 the blue star represents -0.1858 and the red star represents -0.3034. Again, to scrutinise this further, a one-tail test for Spearman correlation with 21d.f for a significance value of 0.1 would have to be less than -0.708. Thus the correlation is not significant.

Analysis of Variance ANOVA

This section summarises the data required to calculate ANOVA (F) to 4 significant figures. All data for these calculations is in Appendix 2. To utilise ANOVA statistical testing effectively, the questionnaire answers have been weighted the same as the spearman correlation shown in Tables 1 and 2, with examples under the Tables.

Table 9 - Equations utilised to calculate ANOVA's F value

Source of Variation	**Sums of Squares**	**Degrees of Freedom**	**Mean Squares**	**F**
Between Treatments (Regression)	SSB = $\sum n_j(y_j - \hat{y})^2$	$k-1$	$MSB = \frac{SSB}{k-1}$	$F = \frac{MSB}{MSE}$
Error (Residual)	SSE = $\sum\sum(y_n - \hat{y}_j)^2$	$N-k$	$MSE = \frac{SSE}{N-k}$	
Total	SST = $\sum\sum(y_n - \hat{y}_j)^2$	$N-1$		

Table 9 show the formulae used to calculate the ANOVA F value. It tests the Construction Industry and the Higher Education Institution as groups regarding their' knowledge of sustainability' against regression, residual and the total. This allows for a comprehensive analysis defining if the current knowledge of sustainability within construction and education institutions is significant or not against the hypothesis.

Hypothesis: the null hypothesis for this test is that there is no difference between the means of the Construction Industry and the Higher Education Institution results. This hypothesis will be tested against the individual and groups of sustainability topics.

Individual sustainability topics ANOVA Results

Table 10: ANOVA data set for groups knowledge of each sustainability topic

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F
Between Treatments	1497.96	1	1497.96	18.58
Error (or Residual)	3627.72	45	80.60	
Total	5125.68	45		

To test the level of significance, we select a confidence level, the table below shows the different confidence levels selected for the ANOVA test.

Table 11: F-values for confidence level of F (1,45)

Confidence Level	0.1 (10%)	0.05 (5%)	0.01 (1%)
F value	2.820	4.057	7.234

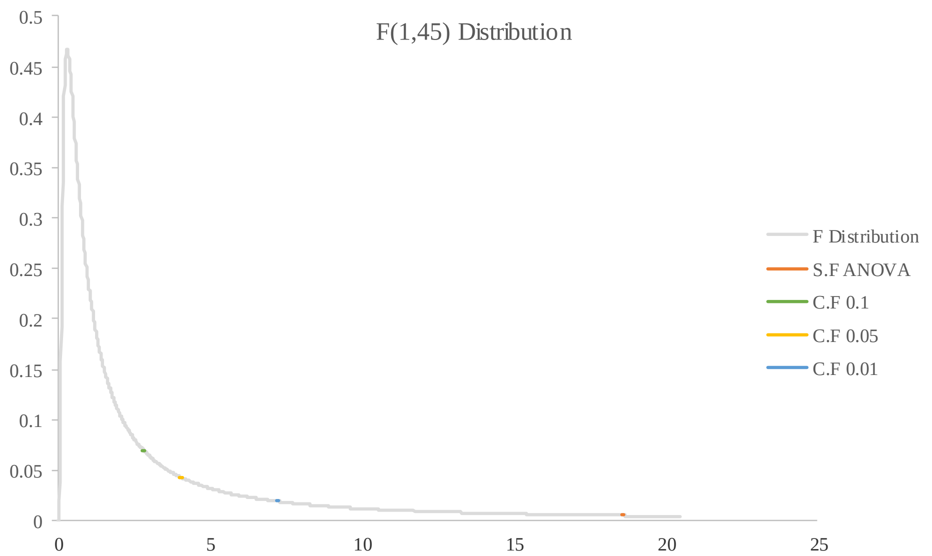

Figure 9: F Distribution graph F (1,45) with confidence levels and significant figure plotted

For an accurate analysis of the ANOVA test, Figure 9 illustrates the distribution graph F (1,45). Along with the distribution graph, the confidence levels and the significant figure (F value) from our ANOVA test have been plotted. The F value of 18.58 far exceeds the 1% confidence level. Therefore we have enough evidence to reject the null hypothesis. By rejecting the null hypothesis, we are stating that with a confidence level of 1% that there is a difference between the Construction Industry's and the Higher Education Institution's knowledge of sustainability.

Table 12: ANOVA data set for groups Summarised into the sustainability categories

Source of Variation	**Sums of Squares**	**Degrees of Freedom**	**Mean Squares**	**F**
Between Treatments	571.88	1	571.88	14.46
Error (or Residual)	435.06	11	39.55	
Total	1006.94	11		

To test the level of significance we select a confidence level. The table below shows the different confidence levels selected for the ANOVA test.

Table 13: F-values for confidence level of F (1,11)

Confidence Level	0.1 (10%)	0.05 (5%)	0.01 (1%)	0.001 (0.1%)
F value	3.225	4.844	9.646	19.68

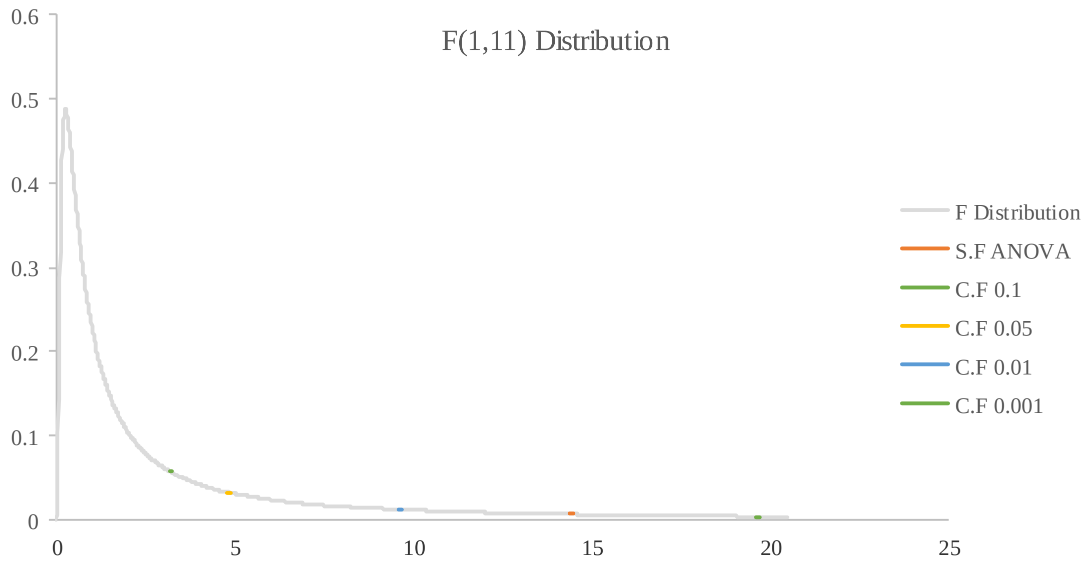

Figure 10: F Distribution graph F (1,11) with confidence levels and significant figure plotted.

For a thorough analysis of the ANOVA test, Figure 10 illustrates the distribution graph F (1,11) with plots of our significant figure and the confidence levels. The F value of 14.46 far exceeds the 1% confidence level but does not exceed the 0.1% confidence level. This means we have enough evidence to reject the null hypothesis at a 1% confidence level but not evidence to reject at 0.1% confidence level. By rejecting the null hypothesis, we are stating that with a confidence level of 1% there is a difference between the Construction Industry's and the Higher Education Institution's knowledge of sustainability, hence providing further evidence to our individual claim

DISCUSSION

The ANOVA statistical testing proved that there is a difference in the mean value of knowledge of sustainable topics' and groups between the Construction Industry and the Higher Education Institution staff members at a confidence level of 1%. This demonstrates that the higher education insttitution has more knowledge of sustainability topics than the construction industry. The means of improving this within the construction industry is by educate the higher education students who will be future of the industry.

Based on the result of the Construction Industry, cost is always highlighted as the most significant factor as, without financial sustainability, a company would not be able to operate at all. Health and safety are another significant factor for the Construction Industry as their ethos is "zero harm – everyone home safe everyday". These key points highlight how company-led learning can influence the whole workforce's ethos and level of knowledge of specific topics surrounding sustainability. By encouraging more professional input into the modules being offer at the higher education institution will direct effect on construction industry performance.

One of the main results that one can conclude from this study is the direct comparison between 'level of knowledge' against 'the amount the topic is used and taught'. The analysis as demonstrates the positive correlation between the 'more knowledge' a practicing professional has and the likelihood of them using this in their daily duties. Two of the least used topics by practicing Quantity Surveyors within the Construction Industry are Climate Change and Social Assessment Methods. Comparatively, the result highlights that these two topics are not taught at 80% in all Higher Education courses. The spearman statistical test for 'knowledge' against 'use of knowledge' further reiterates this point. Figure 1.7 shows a strong positive correlation between the 'amount of knowledge' one may have against the 'amount one may use this knowledge.' Hence, if the topic is not taught when the practicing Quantity Surveyors are at the beginning of their careers, in education, the topic will not be used and therefore not embedded into the industry.

The Construction Industry's responses convey that 75% of all respondents could at least explain the sustainability topics with 30% of their knowledge originating from education. This is the most significant percentage of the source of the Construction Industry's employee's knowledge, symbolising how important the initial education of practicing Quantity Surveyors is. Building on this, the commercial management personnel of the industry states that over 25% of their knowledge is sourced from their company. The two clear main contributors of embedding sustainability into the Quantity Surveying trade and construction industry is through education combined with company training and practice.

Higher Education institutions need to improve thier interactions with industry professionals and the professional bodies.

The Construction Industry's commercial team's attitude towards sustainability is skewed towards their two main priorities, cost and health and safety. Although the Construction Industry's knowledge of cost and health and safety is a positivity, neglecting the other topics surrounding sustainability, allowing inefficiencies and excess waste. Overall, their attitude towards sustainability is perceived as poor due to inefficient knowledge and their weighted score under sixty regarding fourteen of the twenty-three topics based on sustainability. For sustainability to be embedded into the Construction Industry, the professionals need to have the correct attitude, thus conveying that their attitude for sustainability must stem from their education. The result illustrates that only 40% of courses include sustainability topics in their modules. With a limited amount of sustainability being taught, it is no surprise that both the industry and educational institution are still showing poor attitudes towards sustainability.

This research exposed that market-leading construction companies are unaware of their overarching responsibility to educate their Quantity Surveying staff about sustainability. This reveals that the role of a construction company does not end at employment, they have to communicate with educational institutes, such as universities and professional bodies to ensure their staff are up to date with modern sustainability topics, therefore, ensuring sustainable development targets are being achieved.

The results of this research allude to the fact that although higher education faculties possess thorough knowledge of sustainability topics, they are also unaware of their responsibility to educate their students of these given topics. The role of the higher education is to embed sustainability knowledge into their courses, if not they failed the continuation of 'knowledge train'.

The chartered professionals within the Construction Industry's commercial team have gained much of their knowledge from their professional body. The connection between the construction industry's chartered professionals and the higher institutions faculty is the continuous learning gained after the initial education, which the construction industry does not offer. The experience of learning from professional bodies has aided and improved the knowledge of all chartered professionals, which could be the missing link for the lack of knowledge based on sustainability in the construction industry. From the research, the Higher Education Institutions, generally have a better knowledge of the topics surrounding sustainability than the commercial team at the Construction Industry. This signifies that the construction industry has a gap in knowledge compared to the wealth of knowledge that the higher education has to offer. With a lack of knowledge also comes a lack of use. If the construction industry does not provide this knowledge, it will always be deemed underperforming and inefficient.

CONCLUSION AND RECOMMENDATIONS

Sustainability, or sustainable development as it is known in the construction industry, is the current buzzword for our modern society. As with all buzz words and trends negative connotations when acting adversely. The minimum expected standards for construction projects are the government's laws and legislations written and published. Many construction companies will also incorporate the rules and regulations set by professional bodies. However, their own company's ethos may over-rule this ethical approach, especially in times of financial difficulty. With financial hardship also comes financial opportunities or gain. The construction industry is one of the biggest GDP providers in every country, therefore an enormous influence on each country's economy.

This research has shone a light on the attitude of professional bodies towards sustainable development. Chartered professionals generally have more knowledge of sustainability topics than non-chartered professionals. Although professional bodies do not have a direct responsibility to sustainable development (as they do not carry out any construction activities), they continue to deliver sustainable knowledge to their members while pursuing sustainable development. Combining the initial education from universities with continual education from professional bodies allows for practicing Quantity Surveyors to address most (if not all) topics based on sustainability. This research concludes that specific categories based on sustainability, background knowledge and economic issues are already embedded into the industry. However, both the construction and education industries must enhance their positions of power to develop the understanding and use of sustainable development.

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Appendix 1: Spearman Correlation tables of data

Data Set 1: Spearman Correlation of the Construction Industry Sustainable knowledge against Use						
What is your knowledge of each sustainability topic?	Weighted Knowledge	Weighted Use	Knowledge Rank	Use Rank	difference between Ranks (d)	d^2
Sustainable development & construction	57.50	28.21	11	13	-2	4
Climate change	65.00	18.42	8	20	-12	144
Impact of the construction industry on the environment	64.38	34.62	9	8	1	1
Impact of a Quantity Surveyor on the sustainable development and the environment	54.38	28.21	12	14	-2	4
Procurement	73.13	69.87	1	1	0	0
Changes to building regulations	51.25	14.10	14	23	-9	81
Government and global policy changes. e.g. EU directives, construction 2025 etc.	43.13	15.38	22	22	0	0
Protecting and enhancing the built environment	50.00	26.92	16	15	1	1
EMS, EIA and BREAAM	45.63	19.87	21	19	2	4
Reducing energy consumption, greenhouse emissions, waste, transport and water usage.	58.13	30.13	10	10	0	0
Carbon agenda	45.63	21.15	20	17	3	9
Ethical sourcing	53.75	28.95	13	11	2	4
Health and safety	68.75	69.74	3	2	1	1
Social assessment methods	36.88	16.22	23	21	2	4
Cost benefit analysis	65.00	45.51	7	6	1	1
Employment, development and training	65.63	52.56	5	5	0	0
Cost planning and management	71.88	66.45	2	3	-1	1
Value management	67.50	57.05	4	4	0	0
Life cycle costing	65.63	34.21	6	9	-3	9
Financial incentives - subsidies, aggregate tax, carbon credit etc.	48.13	20.51	19	18	1	1
Renewable energy technologies	50.63	23.08	15	16	-1	1
Software - BIM, etc.	49.38	28.38	17	12	5	25
Information control and management - e-business	48.75	40.38	18	7	11	121

Data Set 2: Spearman Correlation of the Construction Industry Sustainable Knowledge against Sustainable Source of Knowledge

What is your knowledge of each sustainability topic?	Weighted Knowledge	Weighted Source of Knowledge	Knowledge Rank	Source Rank	difference between Ranks (d)	d^2
Sustainable development & construction	57.50	52.27	11	9	2	4
Climate change	65.00	47.84	7	17	-10	100
Impact of the construction industry on the environment	64.38	50.38	9	14	-5	25
Impact of a Quantity Surveyor on the sustainable development and the environment	54.38	51.61	12	10	2	4
Procurement	73.13	57.53	1	4	-3	9
Changes to building regulations	51.25	45.54	14	20	-6	36
Government and global policy changes. e.g. EU directives, construction 2025 etc.	43.13	43.50	22	22	0	0
Protecting and enhancing the built environment	50.00	51.25	16	11	5	25
EMS, EIA and BREAAM	45.63	46.93	20	19	1	1
Reducing energy consumption, greenhouse emissions, waste, transport and water usage.	58.13	50.38	10	13	-3	9
Carbon agenda	45.63	45.37	21	21	0	0
Ethical sourcing	53.75	54.84	13	6	7	49
Health and safety	68.75	58.90	3	2	1	1
Social assessment methods	36.88	39.29	23	23	0	0
Cost benefit analysis	65.00	52.86	8	8	0	0
Employment, development and training	65.63	59.19	5	1	4	16
Cost planning and management	71.88	58.23	2	3	-1	1
Value management	67.50	56.58	4	5	-1	1
Life cycle costing	65.63	53.04	6	7	-1	1
Financial incentives - subsidies, aggregate tax, carbon credit etc.	48.13	47.37	19	18	1	1
Renewable energy technologies	50.63	50.37	15	15	0	0
Software - BIM, etc.	49.38	50.41	17	12	5	25
Information control and management - e-business	48.75	48.41	18	16	2	4

Data Set 3: Spearman Correlation of the Higher Education Industry Sustainable Knowledge against Sustainable Source of Knowledge

What is your knowledge of each sustainability topic?	Weighted Knowledge	Weighted Source of Knowledge	Knowledge Rank	Source Rank	difference between Ranks (d)	d^2
Sustainable development & construction	70.84	35.71	8	11	-3	9
Climate change	79.17	35.72	3	8	-5	25
Impact of the construction industry on the environment	75.01	35.71	4	9	-5	25
Impact of a Quantity Surveyor on the sustainable development and the environment	62.54	20.83	17	23	-6	36
Procurement	62.55	20.84	15	21	-6	36
Changes to building regulations	70.83	29.17	11	13	-2	4
Government and global policy changes. e.g. EU directives, construction 2025 etc.	75.00	37.50	5	6	-1	1
Protecting and enhancing the built environment	75.00	37.54	6	5	1	1
EMS, EIA and BREAAM	58.34	37.55	21	4	17	289
Reducing energy consumption, greenhouse emissions, waste, transport and water usage.	66.67	46.88	12	1	11	121
Carbon agenda	70.83	35.72	10	7	3	9
Ethical sourcing	62.49	29.16	20	18	2	4
Health and safety	66.67	29.16	13	16	-3	9
Social assessment methods	50.00	20.83	23	22	1	1
Cost benefit analysis	62.50	29.16	19	17	2	4
Employment, development and training	66.66	29.16	14	19	-5	25
Cost planning and management	62.54	29.17	16	15	1	1
Value management	62.50	29.17	18	14	4	16
Life cycle costing	70.83	29.17	9	12	-3	9
Financial incentives - subsidies, aggregate tax, carbon credit etc.	58.33	25.00	22	20	2	4
Renewable energy technologies	83.33	45.00	1	2	-1	1
Software - BIM, etc.	79.17	39.29	2	3	-1	1
Information control and management - e-business	70.84	35.71	7	10	-3	9

Data Set 4: Spearman Correlation of Sustainable knowledge the Construction Industry (CI) against the Higher Education Industry (HEI)

What is your knowledge of each sustainability topic?	CI Weighted Knowledge	HEI Weighted knowledge	CI Knowledge Rank	HEI Knowledge Rank	difference between Ranks (d)	d^2
Sustainable development & construction	52.27	70.83	9	11	-2	4
Climate change	47.84	79.17	17	3	14	196
Impact of the construction industry on the environment	50.38	75.00	14	5	9	81
Impact of a Quantity Surveyor on the sustainable development and the environment	51.61	62.50	10	19	-9	81
Procurement	57.53	62.50	4	18	-14	196
Changes to building regulations	45.54	70.83	20	10	10	100
Government and global policy changes. e.g. EU directives, construction 2025 etc.	43.50	75.01	22	4	18	324
Protecting and enhancing the built environment	51.25	75.00	11	6	5	25
EMS, EIA and BREAAM	46.93	58.33	19	21	-2	4
Reducing energy consumption, greenhouse emissions, waste, transport and water usage.	50.38	66.66	13	13	0	0
Carbon agenda	45.37	70.84	21	7	14	196
Ethical sourcing	54.84	62.51	6	15	-9	81
Health and safety	58.90	66.66	2	14	-12	144
Social assessment methods	39.29	50.00	23	23	0	0
Cost benefit analysis	52.86	62.50	8	16	-8	64
Employment, development and training	59.19	66.67	1	12	-11	121
Cost planning and management	58.23	62.50	3	17	-14	196
Value management	56.58	62.50	5	20	-15	225
Life cycle costing	53.04	70.83	7	8	-1	1
Financial incentives - subsidies, aggregate tax, carbon credit etc.	47.37	58.33	18	22	-4	16
Renewable energy technologies	50.37	83.33	15	1	14	196
Software - BIM, etc.	50.41	79.17	12	2	10	100
Information control and management - e-business	48.41	70.83	16	9	7	49

Data set 5: Spearman Correlation of Sustainable Source of Knowledge the Construction Industry (CI) against the Higher Education Industry (HEI)

What is your knowledge of each sustainability topic?	CI Weighted Source of Knowledge	HEI Weighted Source of Knowledge	CI Source Rank	HEI Source Rank	difference between Ranks (d)	d^2
Sustainable development & construction	57.50	35.71	11	11	0	0
Climate change	65.00	35.71	7	8	-1	1
Impact of the construction industry on the environment	64.38	35.72	9	7	2	4
Impact of a Quantity Surveyor on the sustainable development and the environment	54.38	20.83	12	23	-11	121
Procurement	73.13	20.83	1	22	-21	441
Changes to building regulations	51.25	29.17	14	12	2	4
Government and global policy changes. e.g. EU directives, construction 2025 etc.	43.13	37.50	22	5	17	289
Protecting and enhancing the built environment	50.00	37.50	16	4	12	144
EMS, EIA and BREAAM	45.63	37.50	20	6	14	196
Reducing energy consumption, greenhouse emissions, waste, transport and water usage.	58.13	46.88	10	1	9	81
Carbon agenda	45.63	35.71	21	10	11	121
Ethical sourcing	53.75	29.16	13	19	-6	36
Health and safety	68.75	29.17	3	14	-11	121
Social assessment methods	36.88	20.83	23	21	2	4
Cost benefit analysis	65.00	29.16	8	16	-8	64
Employment, development and training	65.63	29.16	5	18	-13	169
Cost planning and management	71.88	29.16	2	17	-15	225
Value management	67.50	29.17	4	15	-11	121
Life cycle costing	65.63	29.17	6	13	-7	49
Financial incentives - subsidies, aggregate tax, carbon credit etc.	48.13	25.00	19	20	-1	1
Renewable energy technologies	50.63	45.00	15	2	13	169
Software - BIM, etc.	49.38	39.29	17	3	14	196
Information control and management - e-business	48.75	35.71	18	9	9	81

Appendix 2: ANOVA Correlation tables of data

Formula	y	$\hat{y}_i$	$\hat{y}$	$\sum\sum(\hat{y}_i - \hat{y})^2$	$\sum\sum n_j(y - \bar{y}_i)^2$	$\sum\sum(y - \hat{y}_j)^2$
What is your knowledge of each sustainability topic?	Weighted scores	Weighted scores Average Per Group	Weighted Average of all Scores	Total sum of squares (Regression)	Total sum of Squares (Residual)	Total sum of Squares
Sustainable development & construction	70.83				8.40	74.05
Climate change	79.17				126.16	286.91
Impact of the construction industry on the environment	75.00				49.92	163.12
Impact of a Quantity Surveyor on the sustainable development and the environment	62.50				29.54	0.07
Procurement	62.50				29.54	0.07
Changes to building regulations	70.83				8.40	74.05
Government and global policy changes. e.g. EU directives, construction 2025 etc.	75.00				49.92	163.12
Protecting and enhancing the built environment	75.00				49.92	163.12
EMS, EIA and BREAAM	58.33				92.19	15.17
Reducing energy consumption, greenhouse emissions, waste, transport and water usage.	66.67				1.61	19.70
Carbon agenda	70.83	67.93		748.98	8.40	74.05
Ethical sourcing	62.50				29.54	0.07
Health and safety	66.67				1.61	19.70
Social assessment methods	50.00				321.66	149.53
Cost benefit analysis	62.50				29.54	0.07
Employment, development and training	66.67				1.61	19.70
Cost planning and management	62.50				29.54	0.07
Value management	62.50				29.54	0.07
Life cycle costing	70.83				8.40	74.05
Financial incentives - subsidies, aggregate tax, carbon credit etc.	58.33				92.19	15.17
Renewable energy technologies	83.33				237.12	445.42
Software - BIM, etc.	79.17				126.16	286.91
Information control and management - e-business	70.83				8.40	74.05
Sustainable development & construction	57.50		62.23		0.96	22.36
Climate change	65.00				71.88	7.68
Impact of the construction industry on the environment	64.38				61.67	4.61
Impact of a Quantity Surveyor on the sustainable development and the environment	54.38				4.61	61.67
Procurement	73.13				275.67	118.74
Changes to building regulations	51.25				27.79	120.52
Government and global policy changes. e.g. EU directives, construction 2025 etc.	43.13				179.47	364.93
Protecting and enhancing the built environment	50.00				42.53	149.53
EMS, EIA and BREAAM	45.63				118.74	275.67
Reducing energy consumption, greenhouse emissions, waste, transport and water usage.	58.13				2.57	16.84
Carbon agenda	45.63	56.52		748.98	118.74	275.67
Ethical sourcing	53.75				7.68	71.88
Health and safety	68.75				149.53	42.53
Social assessment methods	36.88				385.99	642.79
Cost benefit analysis	65.00				71.88	7.68
Employment, development and training	65.63				82.87	11.54
Cost planning and management	71.88				235.72	93.06
Value management	67.50				120.52	27.79
Life cycle costing	65.63				82.87	11.54
Financial incentives - subsidies, aggregate tax, carbon credit etc.	48.13				70.51	198.90
Renewable energy technologies	50.63				34.77	134.64
Software - BIM, etc.	49.38				51.08	165.21
Information control and management - e-business	48.75				60.40	181.66
Total				**1497.96**	**3627.72**	**5125.68**