

## MATHEMATICAL THEORY OF EVIDENCE TO SUBJECT EXPERTISE DIAGNOSIS

ANDINO MASELENO<sup>1</sup>, PARDIMIN<sup>2</sup>, MIFTACHUL HUDA<sup>3</sup>, RAMLAN<sup>4</sup>  
AMINUDDIN HEHSAN<sup>5</sup>, YUDARIAH MOHAMMAD YUSOF<sup>6</sup>, ZULKIFLEE HARON<sup>5</sup>  
MOHD NASIR RIPIN<sup>5</sup>, NASRUL HISYAM MOHD NOR<sup>3</sup> AND JUHAZREN JUNAIDI<sup>5</sup>

<sup>1</sup>STMIK Pringsewu  
Jalan Wisma Rini No. 9, Pringsewu, Lampung 35373, Indonesia  
andimaselelo@gmail.com

<sup>2</sup>Faculty of Education  
Universitas Sarjanawiyata Tamansiswa  
Jalan Kusumanegara 157, Yogyakarta 55165, Indonesia

<sup>3</sup>Faculty of Islamic Civilisation  
<sup>5</sup>Centre for Fiqh Research in Science and Technology (CFIRST)

<sup>6</sup>Faculty of Science  
Universiti Teknologi Malaysia  
81310 Skudai, Johor Bahru, Johor, Malaysia

<sup>4</sup>Faculty of Education  
Universitas Pasundan  
Jalan Tamansari, Bandung Wetan, Bandung, Jawa Barat 40116, Indonesia

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**ABSTRACT.** *Studies showed it is important to consider learners' level of expertise for possible steps to be taken at an early stage. A research was designed to assess the relevant level of knowledge and skills. This paper proposed the method of mathematical theory of evidence in identifying the subject matter expertise. A questionnaire consisting of thirty items representing the various kinds of knowledge and skills expected of learners at tertiary level was created. The data collected was analysed using Dempster-Shafer theory and the results indicated the degree of belief that ranges from 0 to 10. It was found that learners' expertise can be determined using the mathematical theory of evidence fairly easily. The method provides a rule to combine expertise of students into a single and more informative hint.*

**Keywords:** Subject expertise, Mathematical theory of evidence, Questions, Course, Creativity

**1. Introduction.** Learner's expertise on any subject matter is indicated by culture, learning preferences, cognitive learning styles, and creativity skills [1,2]. It is important to know how the expertise is determined. There are studies carried out to determine knowledge expertise such as using clinical experiment [3], technology cognition [4], psychometric statistical tests [5], and decision theory [6]. In this paper, the method of mathematical theory of evidence or Dempster-Shafer theory to measure subject matter expertise will be described. This method was found to give a more accurate identification of the expertise level. The discussion will first present the literature review that highlights the various ways used in determining the subject matter level of expertise and the related concern of the measurement. This is followed by description of the research carried out, the data analysis, discussion of results, and ends with the conclusion.

**2. Mathematical Theory of Evidence.** The evidence theory can be described as a mathematical branch where the main concern is usually to apply several empirical evidence together so as to develop the actual picture in a person’s thoughts or judgement process [7]. In other words, this theory attempts to use mathematical inferences to help come up with a concrete reasoning on reality. Glenn Shafer who was an assistant professor and author of the book (A Mathematical Theory of Evidence) is often credited for helping to develop this theory as well as popularizing it but the real ideas behind the theory began with Arthur Dempster who was his senior professor [8]. This theory is mainly based on the fact that in both science as well as practical situations, we are obliged to develop our reasoning based on facts that have to be supported using concrete evidence and in the case of this theory, the evidence is numerical [9]. The theory heavily employs the mathematical topic on probability to help come up with various decisions trees as the necessarily evidence required to prove a given reasoning or fact.

**3. Learning Enhancement.** Due to the enhancement in technology, to support learning it is necessary to strengthen the users’ ability with counselling and therapy service to enlarge the learning enhancement [10-12]. It addresses the skills of technology engagement with adaptive care awareness [13,14], particularly the adaptive behavior of teaching competencies into the technology advancement [15,16]. As a result, this wise approach of learning with sustainable engagement assists in enhancing the knowledge, thinking and skills in the promoting stage. In providing the conducive circumstances in the learning, it points out the responsibility awareness incorporated into the service learning based on the compassion [17-19]. With this regard, efforts to strengthen the moral basis should be committed wisely for interaction in the digital era [20,21]. Thus, analytics basis with an innovative approach on learning to improve the personalised capacity learning [22], using the technology, should be engaged to enhance learning with the comprehensive process committed to the achivement [23]. With evaluation for the learning quality through innovative teaching [12,14], attempts carried out in solving the problem for the academic empowerment to support their learning enhancement [24] need to emphasise the entire basis of self-empowerment in the academic problems [25-28]. Thus, diagnostic analysis should be applied in this case in order to enhance the academic achievement based on mathematical theory.

**4. Methodology.** A diagnosis was carried out and a set of thirty questions was created. Mathematical theory of evidence was chosen to analyse the degree of belief based on the students’ responses. A key component of the mathematical theory of evidence that was of interest is on how to combine independent sets of mass assignments, namely the

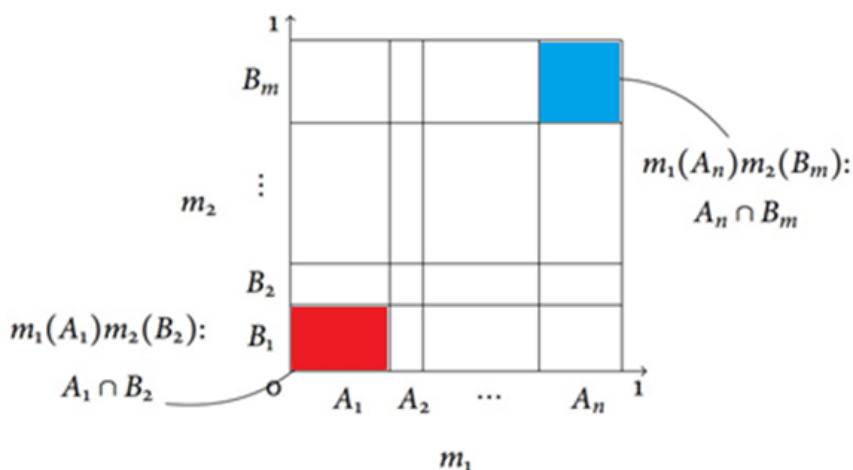


FIGURE 1. Dempster’s rule of visualization

combination of a set of thirty questions that indicate the relevant level of knowledge the user has in a certain field.

Figure 1 shows Dempster’s rule of visualization.  $m_1 \oplus m_2$  is undefined when the denominator  $C$  is 0.  $m_1 \oplus m_2$  is always a mass function. In this research, this would allow us to combine two models to form a combined set of assignments and, consequently, combined belief and plausible values. Specifically it allows us to estimate the combined value of the evidence from the two models. This, in turn, would allow us to construct a new model which combines the evidence from the two models.

Figure 2 shows subject expertise diagnostic process. The process begins with the questions. The mathematical theory of evidence provides a rule to combine evidences from independent observers and into a single and more informative hint. Evidence theory is based on belief function and plausible reasoning. First of all, we must define a frame

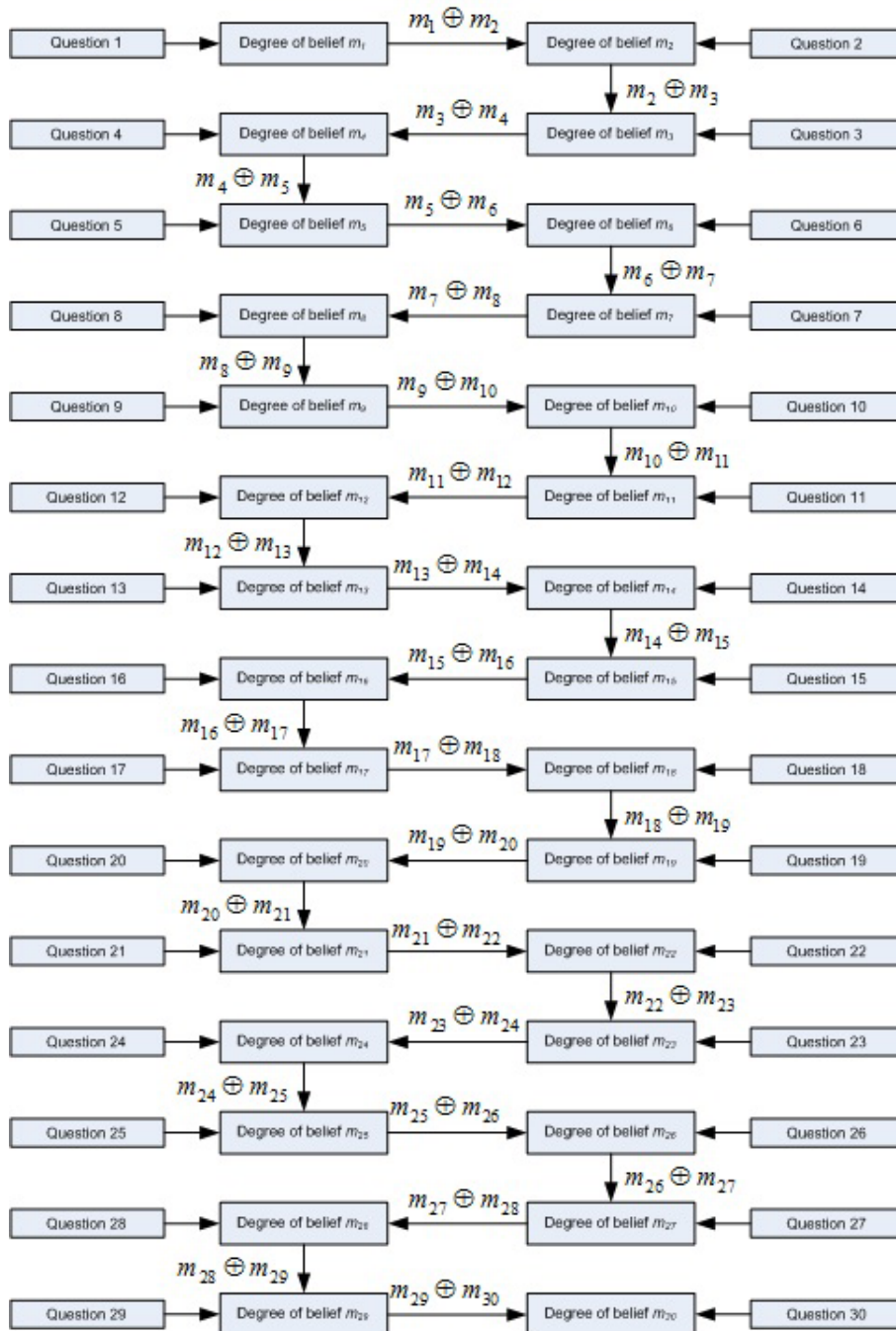


FIGURE 2. Subject expertise diagnostic process

of discernment, indicated by the sign  $\Theta$ . The sign  $2^\Theta$  indicates the set composed of all the subset generated by the frame of discernment. For a hypothesis set, denoted by  $A$ ,  $m(A) \rightarrow [0, 1]$ .

$$m(\emptyset) = 0, \quad \sum_{A \in 2^\Theta} m(A) = 1 \tag{1}$$

$\emptyset$  is the sign of an empty set. The function  $m$  is the degree of belief. Mathematical theory of evidence rule of combination combines two independent sets of mass assignments.

$$(m_1 \oplus m_2)(\emptyset) = 0 \tag{2}$$

where

$$m(A), m_1(B), m_2(C) \rightarrow [0, 1], \quad A \neq \emptyset \tag{3}$$

**5. Implementation and Data Analysis.** Questionnaire was used to collect data on the students' perception of their subject expertise related to knowledge and skills. For details of the items and acronym used to represent the skills (for example W is for writing, etc.) in the questionnaire, please refer to Appendix A. The students' responses were analysed using Dempster's rule of visualization where a rating of 0 or 10 was assigned to represent the degree of belief. The  $m_i$  refers to the students' degree of belief where  $i = 1, 2, 3, \dots, 30$  refers to the items in the questionnaire. The students' responses to the questionnaire are shown in Appendix B. The subject expertise calculation process is as follows: for example from question number 30, how would the understanding of the impact of business on society be rated? As an illustration, consider question/items 30 in the questionnaire. This question indicates that student has ethics and environment skills (EE),  $m_{30}\{\text{EE}\} = 0.7$ . Table 1 below shows the calculation for the combination  $m_{29} \oplus m_{30}$  for subject expertise 29 and subject expertise 30.

TABLE 1. Combining subject expertise 29 and 30

$m_{29}$	$m_{29}$ degree of belief	$m_{30}\{\text{EE}\}$	0.7	$m_{30}\{\Theta\}$	0.3
{W}	<b>0.083</b>	{ $\emptyset$ }	0.058	{W}	0.025
{NA}	<b>0.009</b>	{ $\emptyset$ }	0.006	{NA}	0.003
{ICT}	<b>0.043</b>	{ $\emptyset$ }	0.030	{ICT}	0.013
{M}	<b>0.167</b>	{ $\emptyset$ }	0.117	{M}	0.050
{TW}	<b>0.009</b>	{ $\emptyset$ }	0.006	{TW}	0.003
{P}	<b>0.020</b>	{ $\emptyset$ }	0.014	{P}	0.006
{IB}	<b>0.143</b>	{ $\emptyset$ }	0.100	{IB}	0.043
{IM}	<b>0.112</b>	{ $\emptyset$ }	0.078	{IM}	0.034
{E}	<b>0.333</b>	{ $\emptyset$ }	0.233	{E}	0.100
{EE}	<b>0.076</b>	{EE}	0.053	{EE}	0.023
{ $\Theta$ }	<b>0.005</b>	{EE}	0.003	{ $\Theta$ }	0.002

$$m_{301}\{W\} = 0.025/1 - (0.058 + 0.006 + 0.030 + 0.117 + 0.006 + 0.014 + 0.100 + 0.078 + 0.233) = 0.070$$

$$m_{302}\{NA\} = 0.003/1 - (0.058 + 0.006 + 0.030 + 0.117 + 0.006 + 0.014 + 0.100 + 0.078 + 0.233) = 0.008$$

$$m_{303}\{ICT\} = 0.013/1 - (0.058 + 0.006 + 0.030 + 0.117 + 0.006 + 0.014 + 0.100 + 0.078 + 0.233) = 0.036$$

$$m_{304}\{M\} = 0.050/1 - (0.058 + 0.006 + 0.030 + 0.117 + 0.006 + 0.014 + 0.100 + 0.078 + 0.233) = 0.140$$

$$m_{305}\{TW\} = 0.003/1 - (0.058 + 0.006 + 0.030 + 0.117 + 0.006 + 0.014 + 0.100 + 0.078 + 0.233) = 0.008$$

$$m_{306}\{P\} = 0.006/1 - (0.058 + 0.006 + 0.030 + 0.117 + 0.006 + 0.014 + 0.100 + 0.078 + 0.233) = 0.017$$

$$m_{307}\{IB\} = 0.043/1 - (0.058 + 0.006 + 0.030 + 0.117 + 0.006 + 0.014 + 0.100 + 0.078 + 0.233) = 0.120$$

$$m_{308}\{IM\} = 0.034/1 - (0.058 + 0.006 + 0.030 + 0.117 + 0.006 + 0.014 + 0.100 + 0.078 + 0.233) = 0.095$$

$$m_{309}\{E\} = 0.100/1 - (0.058 + 0.006 + 0.030 + 0.117 + 0.006 + 0.014 + 0.100 + 0.078 + 0.233) = 0.279$$

$$m_{3010}\{EE\} = 0.053 + 0.023 + 0.003/1 - (0.058 + 0.006 + 0.030 + 0.117 + 0.006 + 0.014 + 0.100 + 0.078 + 0.233) = 0.221$$

$$m_{3011}\{\Theta\} = 0.002/1 - (0.058 + 0.006 + 0.030 + 0.117 + 0.006 + 0.014 + 0.100 + 0.078 + 0.233) = 0.006$$

The final ranking of degree of belief was found to be  $E > EE > M > IB > IM > W > ICT > P > NA = TW$ . The final ranking of degree of belief is entrepreneurship > ethics and environment > marketing > international business > information management > writing style > information and communications technology > presentation > numeracy and accounting skills = team working.

**6. Results and Discussion.** Mathematical theory of evidence has been applied to subject expertise diagnosis. Subject expertise includes writing style, numeracy and accounting skills, information and communications technology, marketing, team working, presentation, international business, information management, entrepreneurship, ethics and environment. Based on the calculation, the level of expertise was found, namely, writing style 7%, numeracy and accounting skills 0.8%, information and communications technology 3.6%, marketing 14%, team working 0.8%, presentation 1.7%, international business 12%, information management 9.5%, entrepreneurship 27.9%, ethics and environment 22.1%.

Table 2 shows subject expertise rank. According to the mathematical theory of evidence the combination of null set is 0. From the last calculation we get the final ranking of degree of belief is entrepreneurship  $\{E\} >$  ethics and environment  $\{EE\} >$  marketing  $\{M\} >$  international business  $\{IB\} >$  information management  $\{IM\} >$  writing style  $\{W\} >$  information and communications technology  $\{ICT\} >$  presentation  $\{P\} >$  numeracy and accounting skills  $\{NA\} =$  team working  $\{TW\}$ . Thus, the proposed mathematical theory of evidence enables to easily diagnose and demonstrate the effectiveness of the method.

**7. Conclusion.** In conclusion, this paper aims to introduce the method of mathematical theory of evidence in identifying the subject matter expertise of students. It provides a rule to combine expertise with respect to knowledge and skills of students into a single and more informative hint. Those who achieve a level 10 indicate a high degree of expertise while the smaller number would show the level of novice and may need remedial courses. A user who scores a zero is unlikely to even have a good grasp of knowledge and skills. The results give implication of a potential method to evaluate subject expertise level. As an extension of this work, it is planned to use Hau-Kashyap approach to obtain robust combination method.

TABLE 2. Subject expertise rank

No	W	NA	ICT	M	TW	P	IB	IM	E	EE
1	0.7	> null	= null	= null	= null	= null	= null	= null	= null	= null
2	0.85	> null	= null	= null	= null	= null	= null	= null	= null	= null
3	0.955	> null	= null	= null	= null	= null	= null	= null	= null	= null
4	0.991	> null	= null	= null	= null	= null	= null	= null	= null	= null
5	0.978	> 0.012	> null	= null	= null	= null	= null	= null	= null	= null
6	0.93	> 0.06	> null	= null	= null	= null	= null	= null	= null	= null
7	0.853	> 0.055	< 0.082	> null	= null	= null	= null	= null	= null	= null
8	0.75	> 0.048	< 0.193	> null	= null	= null	= null	= null	= null	= null
9	0.624	> 0.04	< 0.326	> null	= null	= null	= null	= null	= null	= null
10	0.601	> 0.038	< 0.312	> 0.039	> null	= null	= null	= null	= null	= null
11	0.417	> 0.028	< 0.215	< 0.333	> null	= null	= null	= null	= null	= null
12	0.277	> 0.018	< 0.142	< 0.558	> null	= null	= null	= null	= null	= null
13	0.274	> 0.018	< 0.141	< 0.555	> 0.006	> null	= null	= null	= null	= null
14	0.273	> 0.018	< 0.141	< 0.554	> 0.008	> null	= null	= null	= null	= null
15	0.267	> 0.017	< 0.137	< 0.544	> 0.03	> null	= null	= null	= null	= null
16	0.264	> 0.016	< 0.135	< 0.537	> 0.029	> 0.013	> null	= null	= null	= null
17	0.259	> 0.015	< 0.133	< 0.529	> 0.029	= 0.029	> null	= null	= null	= null
18	0.25	> 0.02	< 0.13	< 0.51	> 0.03	< 0.05	> null	= null	= null	= null
19	0.24	> 0.019	< 0.125	< 0.49	> 0.029	< 0.048	> 0.039	> null	= null	= null
20	0.223	> 0.019	< 0.116	< 0.456	> 0.028	< 0.044	< 0.105	> null	= null	= null
21	0.176	> 0.015	< 0.092	< 0.361	> 0.021	< 0.034	< 0.294	> null	= null	= null
22	0.17	> 0.015	< 0.088	< 0.351	> 0.02	< 0.034	< 0.288	> 0.029	> null	= null
23	0.157	> 0.015	< 0.08	< 0.325	> 0.018	< 0.031	< 0.266	> 0.102	> null	= null
24	0.14	> 0.013	< 0.072	< 0.291	> 0.016	< 0.029	< 0.239	> 0.19	> null	= null
25	0.136	> 0.013	< 0.071	< 0.282	> 0.016	< 0.029	< 0.234	> 0.185	> null	= null
26	0.119	> 0.013	< 0.062	< 0.247	> 0.013	< 0.026	< 0.207	> 0.163	> 0.141	> null
27	0.089	> 0.01	< 0.047	< 0.182	> 0.01	< 0.019	< 0.153	> 0.121	< 0.362	> null
28	0.088	> 0.01	< 0.044	< 0.175	> 0.01	< 0.02	< 0.151	> 0.117	< 0.351	> 0.029
29	0.083	> 0.009	< 0.043	< 0.167	> 0.009	< 0.02	< 0.143	> 0.112	< 0.333	> 0.076
30	0.07	> 0.008	< 0.036	< 0.14	> 0.008	< 0.017	< 0.12	> 0.095	< 0.279	> 0.221

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**Appendix A.***Questionnaire on knowledge and skills of subject expertise*

No	Questions	Subject Expertise
1	How do you feel about your writing ability for undertaking university studies?	Writing Style {W}
2	Do you feel your writing ability comes easily or do you feel it is a difficult process?	Writing Style {W}
3	What are your feelings about your own writing style?	Writing Style {W}
4	How would you rate your writing skills?	Writing Style {W}
5	How do you feel about your ability to do accounting (e.g., sales and purchase related skills)?	Numeracy and Accounting Skills {NA}
6	Do you feel your maths abilities come easily or do you feel this is a difficult process?	Numeracy and Accounting Skills {NA}
7	How do you feel about using computers for completing assignments?	Information and Communications Technology {ICT}
8	How do you feel about your typing abilities?	Information and Communications Technology {ICT}
9	How do you rate your level of Internet skills?	Information and Communications Technology {ICT}
10	How do you feel about marketing a product or service?	Marketing {M}
11	What level of confidence do you feel in being able to sell, directly or indirectly?	Marketing {M}
12	What is your level of understanding of the marketing mix?	Marketing {M}
13	How do you feel about working in small groups?	Team Working {TW}
14	How do you feel about working in large groups?	Team Working {TW}
15	Do you like working on your own?	Team Working {TW}
16	How do you feel about presenting verbally to a group of people you know?	Presentation {P}
17	How do you feel about presenting verbally to a group of people you do not know?	Presentation {P}
18	How would you rate your own ability in presenting?	Presentation {P}
19	Do you communicate with people in other countries?	International Business {IB}
20	Do you conduct international communications via e-mail?	International Business {IB}
21	How would you rate your understanding of international business issues?	International Business {IB}
22	Do you feel you are able to organise your work in an efficient way?	Information Management {IM}
23	How do you feel about managing digital information from research journal?	Information Management {IM}
24	How would you rate your ability in business information management?	Information Management {IM}
25	Do you feel you have techniques to support you in being imaginative?	Entrepreneurship {E}
26	How confident do you feel in making the most of opportunities that you receive?	Entrepreneurship {E}
27	How would you rate your ability at being entrepreneurial?	Entrepreneurship {E}
28	How would you rate your awareness of the environmental implications of global business?	Ethics and Environment {EE}
29	How would you rate your understanding of business ethics?	Ethics and Environment {EE}
30	How would you rate your understanding of the impact of business on society?	Ethics and Environment {EE}



**Appendix B.***Perception on knowledge and skills of subject expertise*

No	Questions	Answer	Degree of Belief
<b>Writing Style {W}</b>			
1	How do you feel about your writing ability for undertaking university studies?	7	0.7
2	Do you feel your writing ability comes easily or do you feel it is a difficult process?	5	0.5
3	What are your feelings about your own writing style?	4	0.4
4	How would you rate your writing skills?	8	0.8
<b>Numeracy and Accounting Skills {NA}</b>			
5	How do you feel about your ability to do accounting (e.g., sales and purchase related skills)?	6	0.6
6	Do you feel your maths abilities come easily or do you feel this is a difficult process?	7	0.7
<b>Information and Communications Technology {ICT}</b>			
7	How do you feel about using computers for completing assignments?	9	0.9
8	How do you feel about your typing abilities?	6	0.6
9	How do you rate your level of Internet skills?	5	0.5
<b>Marketing {M}</b>			
10	How do you feel about marketing a product or service?	8	0.8
11	What level of confidence do you feel in being able to sell, directly or indirectly?	9	0.9
12	What is your level of understanding of the marketing mix?	6	0.6
<b>Team Working {TW}</b>			
13	How do you feel about working in small groups?	5	0.5
14	How do you feel about working in large groups?	2	0.2
15	Do you like working on your own?	6	0.6
<b>Presentation {P}</b>			
16	How do you feel about presenting verbally to a group of people you know?	7	0.7
17	How do you feel about presenting verbally to a group of people you do not know?	5	0.5
18	How would you rate your own ability in presenting?	5	0.5
<b>International Business {IB}</b>			
19	Do you communicate with people in other countries?	8	0.8
20	Do you conduct international communications via e-mail?	6	0.6
21	How would you rate your understanding of international business issues?	7	0.7
<b>Information Management {IM}</b>			
22	Do you feel you are able to organise your work in an efficient way?	8	0.8
23	How do you feel about managing digital information from research journal?	7	0.7
24	How would you rate your ability in business information management?	5	0.5
<b>Entrepreneurship {E}</b>			
25	Do you feel you have techniques to support you in being imaginative?	7	0.7
26	How confident do you feel in making the most of opportunities that you receive?	8	0.8
27	How would you rate your ability at being entrepreneurial?	7	0.7
<b>Ethics and Environment {EE}</b>			
28	How would you rate your awareness of the environmental implications of global business?	8	0.8
29	How would you rate your understanding of business ethics?	6	0.6
30	How would you rate your understanding of the impact of business on society?	7	0.7