Full Paper

Introduction

Remotely accessible laboratories have been used to support engineering education over the last twenty years or so (Aktan, Bohus, Crowl, & Shor, 1996). There is an ever increasing number of remote laboratory initiatives around the globe [e.g. www.labshare.edu.au, ilab.mit.edu, www.golabz.eu]. As remote laboratories have matured, sophistication has increased technically, pedagogically, and organizationally (Gomes & Bogosyan, 2009). Student outcomes, in certain applications and certain classifications of learning outcomes, have been shown to be higher with remote labs than for either traditional proximate labs (hands-on) or virtual labs (computer simulations) (Lindsay & Good, 2005). Yet, for all the interest, investment, and successes, many remote laboratories are under used. Hence questions arise as to how to provide relevant information to decision-makers regarding the appropriate adoption of remotely accessible laboratories.

There are many different ways of encouraging the adoption of a remote engineering instructional laboratory (REIL). A decision whether to adopt an REIL into teaching practices is usually made by a department, school, or program, or by an individual academic. Assuming that informed decisions are preferable to uninformed decisions, information regarding an REIL is needed by engineering teachers faced with an REIL adoption decision. A key question thus relates to the relevance of various different categories of information that may help to inform such decisions.

This paper presents the results of an investigation into the relative importance of different types of REIL information to teachers who must decide whether or not to use a REIL in their teaching. The specific research question investigated is: *What are the perceptions of educators regarding the relative importance of information about different characteristics of Remotely- Accessible Engineering Instructional Laboratories (REILs), when considering readiness to decide whether to use a REIL for a learning activity?*

The outcomes are likely to be of use in understanding not only the decisions regarding adoption of remote laboratories, but in supporting a wider understanding regarding factors that affect academic's decisions regarding adoption of other educational resources, and hence how such adoption might best be supported.

The rest of this paper will proceed as follows: 2) Methodological Approach; 3) Best Worst Scaling Survey Results; 4) Discussion; 5) Conclusion.

Methodological Approach

Best-Worst-Scaling (BWS) is the methodological approach selected to address the research question. BWS is a stated choice survey methodology with particular strengths in the determination of what individuals value when confronted with a number of competing possibilities (A. Marley & Louviere, 2005). BWS implementations are designed so that each possible choice is considered in comparison to each of the other possible choices (Louviere, Hensher, & Swait, 2000). This contrasts the more familiar Likert Scaling in which choices are considered independently; there are no trade-offs to be made in Likert Scaling because the various choices do not complete with one another (Likert, 1932).

The design for a BWS survey begins with a list of choice items for which a preference ordering is desired. The set of choice items is then presented to the target respondent group in a series of subsets. For each subset of choices, a respondent is required to identify one choice-item as 'Best' (most useful, most desired, of greatest interest, etc.) and one choice- item as 'Worst' (least useful, least desired, of least interest, etc.). Ideally, the choice subsets are organized in such a way that each choice item appears for comparison against the full range of choice items an equal number of times. After the BWS survey has been administered, the raw data will consist of the complete list of choice items; with each choice item having two columns of associated ordinal data. The first column will have a 'Best' count and the second column will have 'Worst' count. The 'Best' count represents the number of times that given choice-item was selected as 'Best' from the various choice subsets in which it appears. The 'Worst' count represents the number of times that a given choice-item was selected as 'Worst' from the various choice subsets in which it appears. The final result is obtained by taking the Best Count and subtracting the Worst Count which yields the Best- Minus-Worst Count. Analysis is straightforward with no sophisticated software required; just rank the choice items in descending order, according to best-minus-worst count.

2.1 Remote Laboratory Information Types

BWS depends upon having a testable set of choice-items. In this case, a testable set of information types (categories) that are characteristic of a REIL; 37 such information categories were identified and subsequently utilized in the BWS survey.

The remote laboratory literature was consulted directly to obtain a collection of information types characteristic of remote laboratories. Twenty five peer-reviewed papers that had remote laboratories as a considered topic were initially viewed. Papers were selected ad-hoc from searches done on Google, ACM, IEEE, IJOE, and others. More than 85 authors were involved in the writing of these papers. Each individual paper was carefully read with an eye towards extracting remote laboratory characteristics as they appeared in the text. For the purposes here, a remote laboratory characteristic is defined as an identifiable property, behaviour, aspect, or feature. The characteristic might be a word or a phrase. Each characteristic, as encountered, was entered into individual cells on a spreadsheet with a column for each paper. After this, a merge and cull was performed. Individual lists were combined, duplicates eliminated, and fungibles were identified and then conflated. The initial list of 1,276 line items was reduced to 876. These 876 line items were then grouped following a procedure detailed in Tuttle, Moulton & Lowe (2015).

Table 1: Testable Set of 37 REIL Information Types with descriptors (information taxonomy)

Category	Information Type
access	**Access control:** Information about controls on which individuals, institutions, and systems can – or cannot – access a remote laboratory.
	Access to people: Information about connecting with individuals that may be involved with remote laboratory operations: students; staff; technicians; administrators; etc.
	Access to resources: Information about the resources (equipment; networks; experiments) that can be accessed via use of a remote laboratory.
	Accessibility: Information about the accessibility of a remote laboratory. Meeting the needs of individuals with disabilities.
organizational	**Administration:** Information about administrative issues and concerns faced by the institution resulting from use of a remote laboratory.
	Change: Information about the kinds of organizational change that may result from use of remote laboratories.
	Community: Information about the larger remote laboratories community.
	Enrollment: Information about the impact on student enrolment as a consequence of using remote laboratories.
	Expense: Information about the institutional costs of developing and maintaining a remote laboratory.
	Income: Information about the potential for an institution to generate income from providing a remote laboratory.
	Location: Information about the location of remote laboratories; the institutions that provide them, and the users that use them.
	Sharing: Information about sharing of remote laboratories between institutions.

teaching and learning	**Assessment:** Information about assessment of student learning resulting from use of a remote laboratory.
	Collaboration: Information about collaboration between students and students, students and teachers, teachers and teachers made possible through use of a remote laboratory.
	Communication: Information about facilitation of communication which can result from use of a remote laboratory.
	Data: Information about the storage, retrieval, aggregation, and/or analysis of experiment data.
	Disciplines: Information about the disciplines represented and supported by remote laboratories.
	Experiments: Information about the experiments that can be conducted using a remote laboratory.
	Learning aids: Information about the learning aids provided within the context of a remote laboratory.
	Pedagogy: Information about the pedagogy related to use of a remote laboratory for teaching and learning.
	Student benefits: Information about the potential benefits to students through use of a remote laboratory.
	Teacher benefits: Information about the potential benefits to teachers through use of a remote laboratory.
	Visualization: Information about information and data visualizations provided by a remote lab.
technical	**Architecture:** Information about the remote laboratory architecture.
	Booking: Information about the remote laboratory booking systems.
	Capabilities: Information about the functional capabilities of a given remote laboratory.
	Devices: information about the devices employed by a remote laboratory.
	Equipment: Information about the sorts of equipment utilized by a given remote laboratory.
	Framework: Information about the remote laboratory framework.
	Interface: Information about the user-interface of a remote laboratory.
	Management: Information about the technical management of a remote laboratory.
	Safety: Information about the safety factors of a remote laboratory.
	Scalability: Information about the scalability of a remote laboratory.
	Security: Information about the security of a remote laboratory.
	Software: Information about the software and software tools found within a remote laboratory
	Support: Information about the kinds of technical support available for a remote laboratory.
	Technologies: Information about the various technologies employed by a remote laboratory.

Best-Worst-Scaling Survey Design

The set of 37 remote laboratory information types is initially unordered. BWS is employed to (possibly) transform the unordered to the ordered. A BWS survey design was chosen with 37 rows and 9 columns: one row for each of the 37 information types and each of the 9 columns containing a different mix of information types. In each row, survey respondents are faced with 9 different remote lab information types. From these nine, respondents must choose one as being ‘Best’, and one as being ‘Worst’. The specific question that was asked was.

"Imagine that you are considering using a ***remote laboratory*** *for teaching an engineering subject. You would like* ***further information*** *about the* ***remote laboratory*** *available to you so you can make an* ***informed decision****. Consider the following list of topics considering the remote labs available to you. Please select one information topic that would be* ***MOST USEFUL*** *and on information topic that would be* ***LEAST USEFUL*** *in helping you decide whether you will use a remote laboratory in teaching your subject."*

Initially, the design was for each respondent to provide answers to all 37 comparison sets. Pilot tests indicated, however, that this produced two undesirable effects: first, that for some, attention began to wander and so later comparisons were reported not to have the same ‘worth’ as earlier comparisons. Second, and worse, is that some people lost interest entirely and closed their browser without completing the exercise. To ameliorate these concerns, the single set of 37 comparisons was changed to three sets of comparisons; two set of 12 and one set of 13. Respondents would be pre-assigned to group alpha (12), beta (12), or gamma (13). The smaller number of comparisons required by an individual increased the likelihood that respondents would remain ‘fresh’ till the end and actually complete the BWS survey exercise. Table 2 shows three examples of comparison sets. Each comparison set is comprised of a different subset of 9 information types.

Table 2: Best-Worst-Scaling 37x9 Survey Design

Id		Info type 1	Info type 2	Info type 3	Info type 4	Info type 5	Info type 6	Info type 7	Info type 8	Info type 9
21	Q6	community	teacher benefits	access to resources	safety	communicati on	access to people	data	experiments	assessment
2	Q17	teacher benefits	scalability	collaboration	change	capabilities	assessment	devices	framework	architecture
7	Q12	collaboration	equipment	fees	access control	student benefits	enrolment	teacher benefits	architecture	learning aids

Implementation, Invitation, Execution

The survey instrument was realized as a bespoke web application. A total of 5173 invitations to participate were sent via email. Email addresses were manually culled from Engineering faculty websites of the 35 Australia institutions which offer a bachelor's degree in engineering. 250 complete responses were obtained, representing a raw response rate of 5%. The actual response rate is slightly better as many invitations resulted in out-of-office replies or bounces. There were 258 incomplete responses and these were not used in the tally. Table 3 shows the complete response breakdown.

Table 3: Complete Response Breakdown

Block	Block Size	Responses	Answers
Alpha	12	70	840
Beta	12	93	1116
Gamma	13	87	1131

Best-Worst-Scaling Survey Results

The BWS survey results are shown in Table 4. Table 4 has the raw counts and orders the information types from Best to Worst. 'Best' is the information type which is perceived by educators to be most useful as decision support for remote lab adoption decisions. The raw data indicate that educators do have information preferences. It is also worth noting that the Best Minus Worst results have a nearly normal distribution

Table 4: Best-Worst-Scaling Survey Results, with preferential ordering, Best to Worst.
Best Count is the number of times the given information type was chosen as 'Best' . Worst Count is the number of times the given information type was chosen as 'Worst'.

A	B	C	D	E	F
Id	Information Type	Best Count	Worst Count	Best Minus Worst	Preference Order
18	experiments	338	10	328	1
21	student benefits	248	18	230	2
26	capabilities	199	12	187	3
3	access to resources	178	11	167	4
23	visualization	143	9	134	5
28	equipment	147	22	125	6
37	technologies	156	35	121	7
19	learning aids	113	22	91	8
13	assessment	121	42	79	9
30	interface	110	32	78	10
36	support	105	28	77	11
14	collaboration	103	36	67	12
20	pedagogy	130	66	64	13
22	teacher benefits	115	56	59	14
2	access to people	92	37	55	15
27	devices	109	56	53	16
16	data	57	35	22	17
35	software	70	51	19	18
15	communication	27	43	-16	19
17	disciplines	52	73	-21	20

4	accessibility	27	55	-28	21
1	access control	45	85	-40	22
9	expense	69	117	-48	23
32	safety	39	90	-51	24
12	sharing	24	81	-57	25
25	booking	51	110	-59	26
33	scalability	35	100	-65	27
31	management	40	131	-91	28
8	enrolment	31	124	-93	29
29	framework	12	127	-115	30
7	community	13	137	-124	31
24	architecture	14	164	-150	32
5	administration	20	172	-152	33
34	security	4	168	-164	34
6	change	17	197	-180	35
11	location	22	240	-218	36
10	income	14	298	-284	37
	Totals	3090	3090	0	

Discussion

Analysis of the data suggests that educators, when asked to consider whether to adopt a remote lab for teaching, do indeed have information preferences. When faced with a decision whether or not to use a remote lab for teaching is a decision; information is required to make an informed decision. Not all information is perceived as equally useful; decision making is better supported by some kinds of information in contrast to others. For example, information regarding the specific experiments offered by an REIL was identified as the most useful to arriving at a decision. At the opposite end the preference spectrum, the income potential of an REIL was identified at the least useful decision aid.

Table 4 presents the results of the Best Worst Scaling survey. Column E contains the Best Minus Worst score. A bigger number means ‘better’, ‘more useful’. Note that there 37 information types with 37 distinct scores. Column F ranks the information types from best (highest) to worst (lowest). Figure 1, below, is an elaboration of the raw ranking in Table 4. The standard error is included and gives each raw ranking a range. The grey horizontal bar is raw best minus worst value. The handlebars on the end of each grey bar show the standard error. The vertical bars indicate overlapping ranges. When ranges overlap, preference order cannot be determined. For example, because of range overlap, it is not possible to determine the preference order between information about assessment and information about pedagogy. Where there is no range overlap, preference order can be stated. For example, assessment information is preferred over information about scalability.

Conclusion

This paper presents the results of an investigation of educators’ perceptions regarding the relative importance of different categories of information, when making decisions about the adoption of remotely accessible engineering laboratories. The results suggest that some categories are perceived as more useful than others. For example, information regarding the specific experiments is perceived to be more useful than information regarding the income potential of an REIL. The outcomes help to improve our understanding decisions about the adoption of remote laboratories. In addition, the outcomes may also be useful in developing a wider understanding regarding factors that affect academic’s decisions regarding the adoption of other educational resources, and how to better inform such decisions.

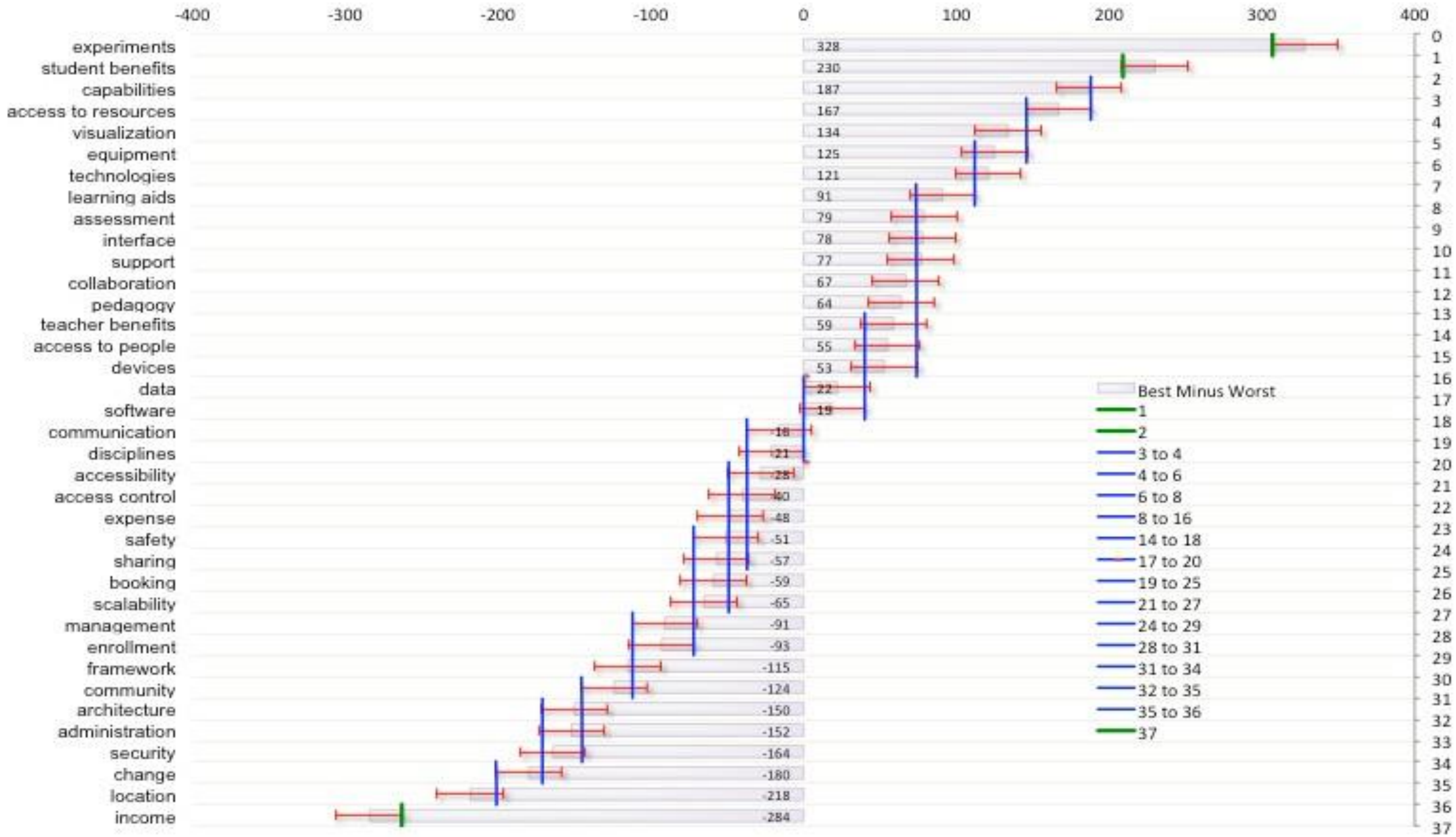

Figure 1: Best Worst Scaling Survey Results With Red Error Bars. Showing approximate preference ordering. Blue Vertical Bars Indicating possible preference overlap.

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