OPEN ACCESS

University of BRISTOL

University of Bristol - Explore Bristol Research
General rights

Using wikis to investigate communication, collaboration and engagement in Capstone engineering design projects

L. Berthoud & J. Gliddon

Published online: 16 Jun 2017.

Submit your article to this journal ⬈

Article views: 57

View related articles ⬈

View Crossmark data ⬈

Taylor & Francis
Taylor & Francis Group

Using wikis to investigate communication, collaboration and engagement in Capstone engineering design projects

L. Berthoud[a] and J. Gliddon[b]

[a]Department of Aerospace Engineering, University of Bristol, Bristol, UK; [b]Technology Enhanced Learning, Academic Registry, University of Bristol, Bristol, UK

ABSTRACT

In today's global Aerospace industry, virtual workspaces are commonly used for collaboration between geographically distributed multidisciplinary teams. This study investigated the use of wikis to look at communication, collaboration and engagement in 'Capstone' team design projects at the end of an engineering degree. Wikis were set up for teams of engineering students from different disciplinary backgrounds and years. The students' perception of the usefulness of the tool were surveyed and the user contribution statistics and content categorisation were analysed for a case study wiki. Recommendations and lessons learned for the deployment of wikis are provided for interested academic staff from other institutions. Wikis were found to be of limited use to investigate levels of communication and collaboration in this study, but may be of interest in other contexts. Wikis were considered a potentially useful tool to track engagement for Capstone design projects in engineering subjects.

1. Introduction

1.1. Aims and objectives

For engineering students, face-to-face communication is seen as the gold standard (Olson and Olson 2000). However, the international and multidisciplinary nature of the Aerospace industry means that teleconferences and emails often take the place of face-to-face meetings. In addition, virtual communal workspaces are frequently used for sharing documents. These workspaces encompass websites, wikis and joint drives. These tools are used for communication and collaboration between geographically distributed teams. Students are familiar with informal social media such as Facebook, but have less experience of these more formal ways of interacting in a professional context. They also have little experience of working as teams, so in the final year of an integrated Master's degree at the University of Bristol they are mentored through a team project by an industrial partner of the University. This is called a 'Capstone' design project. It is of a multidisciplinary nature and the technical challenge is set at a level such that the team need to communicate frequently and collaborate closely to produce a good design. Despite weekly meetings with their groups, academic advisors at this University sometimes find it hard to establish if any of the students are not engaging. This information is useful to carry out early interventions to keep the students on track. For these reasons, the authors wished to investigate whether encouraging the

CONTACT L. Berthoud ✉ lucy.berthoud@bristol.ac.uk

teams to use a wiki, that is, an easily editable set of webpages, might help the team to communicate and the academic advisors track engagement.

1.2. Defining terms

Before investigating, it is useful to define the terms 'communication' and 'collaboration', which are sometimes used interchangeably. The dictionary definition of 'communication' is 'the imparting or exchanging of information by speaking, writing, or using some other medium', whereas the definition of 'collaboration' is 'the action of working with someone to produce something' (Oxford University Press 2015). Whilst these two actions overlap in the exchanging of information, collaboration is creative in nature, as something is produced. Collaboration also involves two active participants, whereas communication may involve a passive receiver (Jackson 2010). A distinction between 'collaboration' and 'cooperation' may also be useful. To summarise previous work by Pinho-Lopes and Macedo, 'cooperation' involves dividing the work into separate subtasks and drawing them together, whereas 'collaboration' involves handling interlinked problems and subtasks (Pinho-Lopes and Macedo 2016).

1.3. Communication tools

With globally dispersed teams and the increasing complexity of projects in industry, communication and collaboration tools have become vital. Engineering technical tools are rapidly evolving in this direction, for example, CAD Product Lifecycle Management offers the possibility of multiple stakeholders having access to technical drawings (Curran, Zhao, and Verhagen 2015). Students use the cloud to share design calculations via cloud spreadsheets, etc. This study is not about technical tools, however, but about offering ways of communicating organisational information, such as tasks to be done, updates and questions to students and of being able to track user contributions for staff. Whilst students are familiar with informal social media, such as Facebook, as organisational tools, industry tends to use a mix of secure shared servers, internal wikis and intranets (internal websites). It was the aim of this project to provide a communication tool/s for the students of a team design project and to use this to track user contributions and interactions between students to study communication in a project.

Several possibilities were assessed, including websites, file-sharing tools and other networking social media tools (Table 1). The status quo would have been to let the students use their own methods (usually a combination of 'Facebook' and 'Dropbox'). However, one of the drivers for changing from the status quo was security of content. The projects were mentored by Aerospace companies and sometimes involved commercially sensitive information. The industry mentors were keen that the design information and communications stayed within a secure environment such as the University Virtual Learning Environment (Blackboard). Whilst all the possibilities considered can track user contributions, some tools make this considerably easier. Other features considered desirable included: file sharing, the ability to form user groups, provision of online comments and

Table 1. Comparison of possible social media tools for communication.

Feature	Wiki within blackboard	Social networking	Website with login	File sharing
Easy tracking of contributions	✓	✓	✗	✗
File sharing	✓	✓	✓	✓
Ability to form user groups	✓	✓	✗	✓
Online comments/feedback	✓	✓	✓	✗
Easy organisation of content	✓	✓	✓	✓
Possibility for remote collaboration	✓	✓	✓	✓
Security	✓	✗	✓	✗
Used in Aerospace industry	✓	✗	✗	✓
Ease of setup	✓	✓	✗	✓

feedback, easy organisation of content and setup and communication methods for remote collaboration (Nanda, Lehto, and Nof 2014). A comparison table of the possibilities considered in this work is given in Table 1. A wiki offered all the features sought, which is why it was selected for this study.

1.4 Wikis in education

A 'wiki' is an easily editable set of webpages to which users can add a narrative, comments, documents, pictures, etc. (the phrase 'wiki-wiki' means 'quick' in Hawaiian; Chao 2007). This makes them an attractive platform for communication and recently, University Virtual Learning Environments have started to include the possibility to set up wikis. These allow students to interact securely within their confines (McLoughlin and Lee 2010), thus satisfying the need for protecting sensitive information.

As more than one author is possible for a wiki, it can be used to help a team communicate. Features such as the possibility to comment on another user's contributions can also encourage collaborative working. Research has shown that wikis can offer interesting advantages for project planning and documentation (Schaffert et al. 2006). It has also been suggested that wikis can be to promote collaboration, including brainstorming and exchange of ideas, coordination of activities, coordination and records of meetings as well as serving as a notepad (Schaffert, Gruber, and Westenthaler 2005).

Wikis have been used in education to facilitate 'not only communication but also the collaborative finding, shaping, and sharing of knowledge' (Reinhold 2006). They allow students to create a learning space where they can develop an idea, gather thoughts and interact at different times and from different places. Another study describes the advantages of wikis as ease and speed of access and version control – a registry of who, what and when changes were made in each document (De Pedro et al. 2006).

Some studies have already reported on students' and lecturers' perceptions of using wikis as a platform for conducting assessed group projects in University courses (Elgort, Smith, and Toland 2008). One of the advantages of wikis is that analysis of user contributions, such as the timing, nature and authorship of page edits can be used to investigate student engagement in a project. A number of studies have drawn on the log data generated by wikis to support their investigations (Forte and Bruckman 2007; Cole 2009; Trentin 2009). A list of wiki metrics already used in studies to measure student engagement is given in Table 2. One study categorised the comment content into 'individual' or 'group' and 'editing', 'collaboration', 'reply' or 'content' (Forte and Bruckman 2007). A further study categorised the content into 'content', 'coordination/co-decision' or 'other' (Trentin 2009).

Several studies have found that wikis do not always have enthusiastic participation (Cole 2009; Judd, Kennedy, and Cropper 2010). One study had no posts at all to their wiki and concluded: 'Further work is needed to determine whether it is possible to create new pedagogic structures of learning to promote collaborative behaviours amongst students that are not directly assessable' (Cole 2009, 146). Another study showed that a small proportion of the students did the bulk of

Table 2. Wiki metrics – measures used to assess student participation by various authors.

Metric	Author
Average edits/week	Forte and Bruckman (2007)
Total Edits	Cole (2009)
Number of edits/page	Larusson and Alterman (2009)
Unique pages edited	Forte and Bruckman (2007) and Trentin (2009)
Number of words	Trentin (2009)
Proportional contribution of text (based on word count)	Judd, Kennedy, and Cropper (2010)
Number of comments	Judd, Kennedy, and Cropper (2010)
Links among wiki clusters	Trentin (2009)
% of students who contributed on one or more days	Forte and Bruckman (2007)

Table 3. Objectives and rationales behind the deployment of the Wiki.

Intended objective	Rationale
1. To give the students an experience of virtual workspaces.	In the global Aerospace industry, geographically distributed teams often need to communicate using virtual workspaces. The wiki can give them an experience of interacting within such a workspace.
2. To encourage all members of group to contribute	With teams, there are frequently complaints that one or two members are not contributing. Wiki entries have a time stamp and the author. This information is available to assessors.
3. To promote collaborative working	Three different degree programmes take the course and this meant that the students did not all know each other or have the same timetable for meetings. It was hoped that the wiki would help the integration of the team.
4. To identify problems early and ensure students keep on course towards success	The instructor can check wikis for progress, offer comments and can intervene if the group appears not to be progressing.
5. To encourage planning	With a large team and a substantial task to accomplish, the teams need to plan and manage their schedule. A wiki centralises the knowledge base, so that all team members know where to look for the latest information.
6. To protect commercially sensitive information	Students work on current projects for Industry partners. Sometimes the latter provide sensitive information which requires protection and is not suitable for a 'Facebook'-type environment.

the work and the majority of contributions were made very late in the task, thus negating the possibility of extensive collaboration (Judd, Kennedy, and Cropper 2010).

1.5. Learning objectives

In this study, it was proposed to see if it is possible and useful to use a wiki to encourage communication and to track team engagement in an Aerospace Capstone design project. The learning objectives of deploying the wiki are listed in Table 3. The aims of the study were to see:

- if students could work with a wiki
- whether a wiki was useful to monitor the individual contributions of team members
- what could be learned from looking at user contribution statistics.

A student survey, wiki contribution statistics and some interviews from a case study group were used to examine these questions.

1.6. The Aerospace Capstone design course at the University of Bristol

A 'Capstone' design project is one which brings together much of the theoretical knowledge learned in taught units to be applied to a design challenge, often set by industrial mentors. Various authors have covered how to organise them for an optimal student learning experience (Marin, Armstrong, and Kays 1999; Todd and Magleby 2005; Smith, Miller, and Seager 2011). In the last year of a four-year integrated Master's in Aerospace Engineering at the University of Bristol, the students spend six months doing a Capstone Design project. Capstone design projects have been integrated in the University of Bristol Aerospace Engineering degree in its present form for the last 20 years. The challenge is to design a full aircraft, helicopter or spacecraft in six months. The design specification is set by industrial partners who are all leading companies in each area: Airbus, Airbus D&S and Leonardo. Assessment is by individual and group reports, as well as by a series of presentations made to both academic staff and industrial partners.

The University of Bristol learning objectives of the Capstone design project are determined by the Chartered Engineering Institution which has accredited the course (the Royal Aeronautical Engineering Society). The learning objectives stipulate that, on successful completion of the project, the students should be able to:

(1) apply the design skills from different modules
(2) apply analytical tools to an industrial design problem
(3) use innovation and creativity in their design
(4) resolve conflicting technical objectives
(5) apply teamwork skills for collaborative effort
(6) publicise the groups findings through written and oral presentation
(7) provide management of a group project

Within these learning objectives, implementation of the wiki falls under number 5 and, to a lesser extent, numbers 4 and 7.

Students on this course come from three different degree programmes: the integrated M.Eng in Aerospace Engineering (85–93%), the MSc in Aerospace Engineering (5–10%) and the integrated M.Eng in Engineering Design (2–5%). Each team/group had 12–14 members although the spacecraft design group was particularly large (15 members). The students were allocated to a group based on their preference for topic: Aircraft, Helicopter or Spacecraft. They were therefore with a group of peers who they may not know and had not chosen. This is analogous to industrial design team.

The team start off with a specification with requirements set by the industrial partners and work towards a Preliminary Design Review (PDR), which is presented in the form of a poster and a report. From kick-off to PDR, the team are all working as generalists on the design. At the PDR stage, the individual team members take on design roles according to the subsystems of the vehicle, for example, for the spacecraft group, there were two power subsystem designers, two mission analysts, two Attitude and Orbit Control engineers, etc. Then, the students work towards a Critical Design Review (CDR), which forms the end of the project, when they give a presentation and write a report for the industrial partners and academics to assess. Students have to schedule their own meetings and time for study, most groups establish a pattern of two meetings a week with a rotating chairman and minute taker.

2. Methodology

2.1. Introduction

The study approach is described in Figure 1. This shows the overall process used and data produced. Firstly, the project was planned by the authors. This involved thinking about the learning objectives, preparing the deployment of the wiki, considering the survey questions to be asked at the end of the year and the analysis metrics. In 2010–2011, a cohort of 59 students took the Capstone Aerospace design course and used the wikis for their projects. At the end of the project, the students' perceptions of the wiki were surveyed, in order to assess whether the wiki was a useable tool for the students. The authors of this paper do not have access to the wikis from that first year. The feedback from the survey was broadly positive and indicated that the idea was worth pursuing. So, in the following year, 2011–2012, a cohort of 102 students took the same course and the wiki was deployed again. This time with more support, including an example wiki. After this course, a case study wiki was selected for detailed analysis and the students from this group were interviewed by one of the authors. All the data were then collated and analysed and conclusions drawn.

2.2. Deployment of the wikis

The wikis were set up within the Blackboard course for the Capstone Design project. Using Blackboard tools, users were assigned to groups corresponding to their teams. Each group had access to their own wiki but could not see the other wikis. The academic advisor for each group could see their own group only. As the wiki was hosted by Blackboard, individuals were required to login to access the wiki.
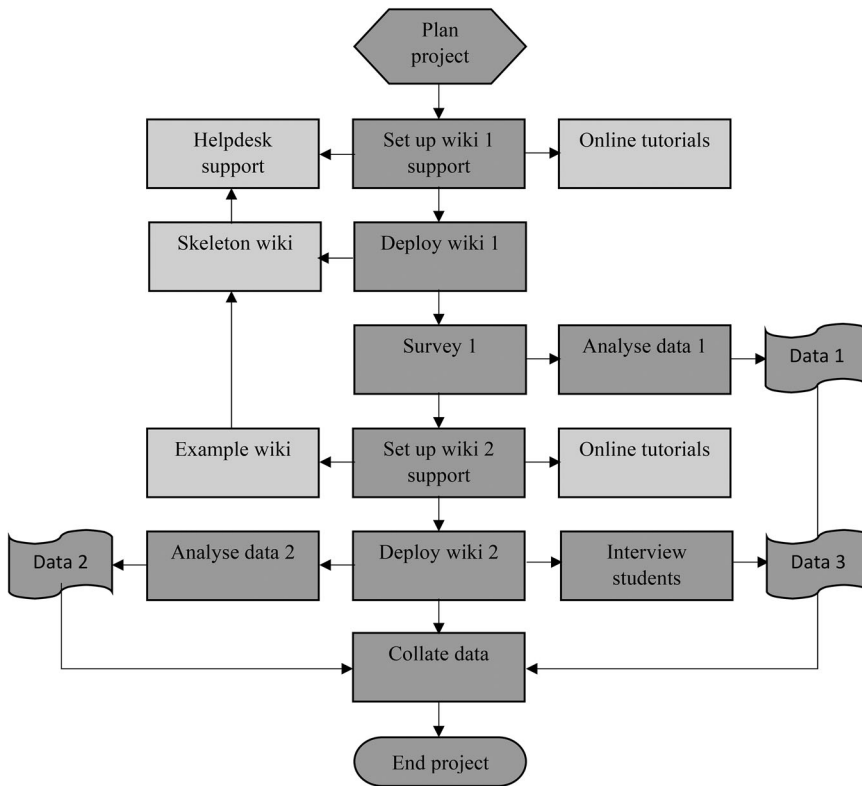
Figure 1. Study approach flowchart.

A basic structure of the wiki was established for the students, with a home page, example pages and instructions on each page as to how to contribute. An instruction video on how to use the wikis was posted on the home page. The wikis included notes and help files for students and the students could access technical help by sending an email to the wiki administrator. Group advisors were also given instructions and provided with the video. One of the authors of this paper gave a briefing at the design project kick-off to explain the approach and the rationale behind it. This author regularly asked the group advisors about their level of interaction with the wiki.

The students were advised specifically 'not to waste time by making the wiki look good!' and to use it for communication and collaborative working ONLY, for example, to do lists, task allocations, data for each subsystem, links to important documents, places to look for ideas, questions for academic and industry advisors. They were advised that the wiki would be checked by the academic advisor at group meetings and that minutes of the meetings should be available on the wiki for the advisor to access.

2.3. Collecting the data

To assess the student perception of the wiki, the 2010–2011 cohort was surveyed at the end of the course (questions are provided in Appendix 1). Out of 59 students, 57 completed the survey – a 97% response rate. The survey was anonymous and was administered electronically. The results of the survey are discussed in Section 3.1.

After the results of this survey and discussions with students and staff, it was considered worth pursuing the use of the wiki for the next academic year in 2011–2012. This time, one of the best team wikis from the 2010–2011 year was given as an example on Blackboard for the following cohort to learn from. As previously mentioned, wikis are particularly suited to providing data on

Table 4. Wiki Metrics used in this study.

Metric	Author
Total edits per person	Cole (2009)
Number of members contributing over time	This paper
Cumulative edits over time	This paper
Edits per person over time	This paper
Number of persons editing per day	This paper
Content category, that is, collaboration, content, editing, individual and group.	Judd, Kennedy, and Cropper (2010)

user contributions, as they provide logs of comments, page edits and contributions by authors with time stamps.

To examine user contributions, the most populated wiki, as judged by number of page edits and page structure, from the 2011–2012 cohort was analysed in detail. The rationale for choosing the most populated one as a case study was as the wikis were not being assessed, only a motivated group would provide a contrast between engaged and less engaged participants (see further discussion of this in Section 4.) The most populated wiki in the 2011–2012 cohort was that constructed by the Spacecraft design group. Some of the metrics from the literature (see Table 2) were used to assess student engagement and some new metrics were proposed to describe contribution over time (see Table 4). A user identifier and edit time was recorded automatically by the wiki software for each edit. Each separate revision was counted, even if revisions were minutes apart. The content was categorised following the same categories as Judd (Judd, Kennedy, and Cropper 2010) – see Section 1.1. Members of the Spacecraft design team were interviewed to investigate their views on the utility of the wiki and the reasons behind their levels of engagement.

3. Results

3.1. Results of survey

Questions asked in the survey in the first year (2010–2011) are given in Appendix A. Question 1 in the survey was: 'Have you used a wiki before you started the project?' Out of the 57 students surveyed, 9 students (16%) said 'yes' and the remaining 48 (84%) said 'no'. None of the staff advising the groups had used one.

Question 2 in the survey asked 'how often did you personally use the wiki as part of the project?' Out of the options: 'less than once a month', 'monthly', 'weekly' and 'more than once a week', 60% of the students said that they had used the wiki at least weekly (see Figure 2). For a project spread out over six months and where two face-to-face meetings a week are already happening, this could be said to constitute regular use. Of the nine students (16%), who had used a wiki before, six (66%) used
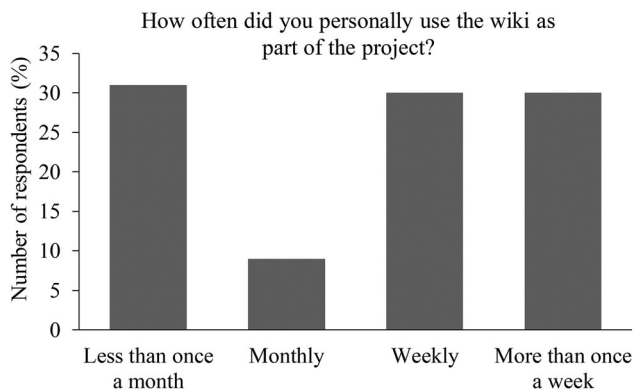
Figure 2. Results of survey of 57 engineering students to establish the frequency of use of the wiki.

the wiki at least weekly. Of the 48 students (84%) who had not used a wiki before, 26 (54%) had used the wiki at least weekly.

The 31% of students who used the wiki 'less than once a month' may correspond to some of the two groups of students in this cohort who did not engage with the wiki at all, that is, no meaningful wiki was produced.

In Question 3 of the survey, students were asked whether they found that the wiki aided collaboration. Their replies are shown in Figure 3. Sixty-two per cent of the students either strongly agreed or agreed that the wiki aided collaboration.

Of the 34 students who used the wiki at least weekly, 31 (91%) agreed/strongly agreed that the wiki aided collaboration.

Question 4 in the survey asked: 'Did you have any technical problems with these tools?' Twelve of the 15 students (21%) said 'yes' and the remaining 35 said 'no'. Of those who had experienced technical problems, the elaboration question 'if yes, please elaborate' comprised the following responses:

Difficulty in editing pages, especially with images on them.

Extremely slow, poor User Interface, doesn't accept HTML.

It froze.

Improvement in the word processor used is needed, otherwise not bad (a bit un-user friendly!)

No technical problems but the wiki was incredibly complicated to navigate.

Not very user friendly.

It often crashed.

Pages have problems to load when containing a large number of data. [*sic*]

Sometimes new edit will cover the whole page, it could be caused by too much content in one page.

Sometimes it went down with Blackboard.

To summarise these comments, the technical problems appeared to be related to:

- lack of user-friendliness
- difficulty loading
- crashing (along with Blackboard).
- limited ability to contain spreadsheets

Question 5 in the survey asked the students to complete the sentence: 'In using the wiki, I found the following very helpful'. The results are shown in Figure 4. It is clear that the students found their colleagues the most helpful in learning how to use this new tool.
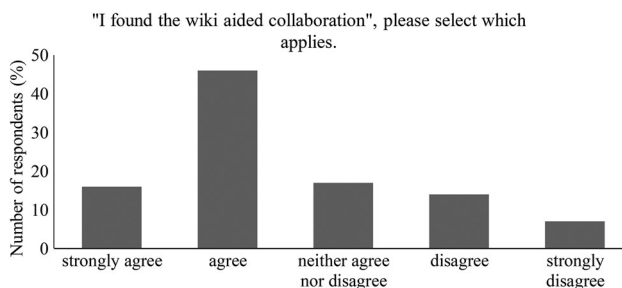

Figure 3. Results of survey of 57 engineering students to establish their perception of whether the wiki aided collaboration.
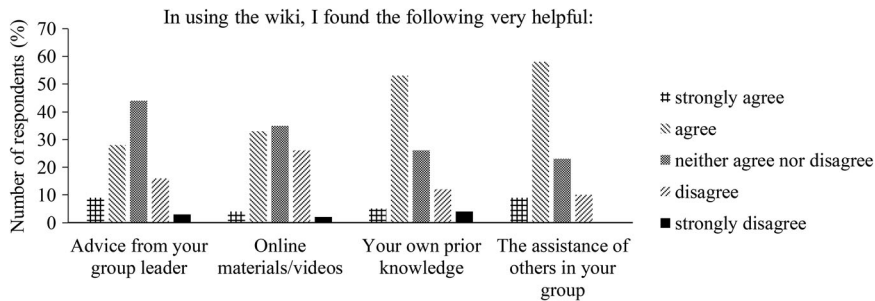
Figure 4. Results of survey of 57 engineering students to see what was helpful in learning how to use the wiki.

Question 6 in the survey asked 'Please use this area for any comments about the whole wiki process'. The comments included the following:

Overall very useful

After spending some time on it, it gets familiar and easy to use.

Blackboard's new layout was a nightmare to use, and there were SO many different areas to go on and folders to try and find things on, it was actually a hindrance rather than just not being useful

Good resource for project announcements and uploading lecture notes etc. Wiki is a nice idea but not really practical since it is far easier to discuss in person when you see most people every day.

Wiki was good when it worked. A good idea but very often, team members would not look at it for ages when important stuff was there, so maybe we need a system that tells subscribers (the team) about changes to the wiki.

Our group did not use the wiki as we had 4 team meetings a week. We felt that we met up often enough and sent a lot of emails, so we didn't feel the wiki was suitable for our group.

The ability of the wiki to contain spreadsheets is very limited and needs to be improved.

It is clear from these, that some groups felt that they were meeting sufficiently often for a wiki not to contribute greatly to group communication.

3.2. Results from the wiki

From the 2011–2012 cohort, the wikis were mined for their statistical data. Most wikis had between 100 and 200 page edits over the project. Some of the wikis had 6 out of 12 contributors, others had 1 or 2. The reasons for the lack of engagement in the wiki by some of the groups are suggested in the discussion. The spacecraft wiki was exceptional for its high number of total edits at 754 and was taken as a case study to examine further the user contribution statistics and to look at content to establish whether it could be said that the group had used it for communication and collaboration purposes. This study was not a comparative study, but an investigative one, to see what it is possible to elicit from a wiki.

It is worth pointing out that one of the authors of this paper was the mentor of this group and this may also have played a role in the high number of edits and engagement, as more interaction and questioning over the wiki took place.

The spacecraft group had 15 members from 3 different cohorts of 4th year engineering students: 2 from a conversion Master's in Aerospace Engineering (having come from physics), 1 from a Master's in Engineering Design and 12 from the Master's in Aeronautical Engineering. For the purposes of anonymity, these team members have been numbered from 1–15. Their wiki had all 15 members contributing. The lowest member's level of contribution being eight page revisions (1%), the
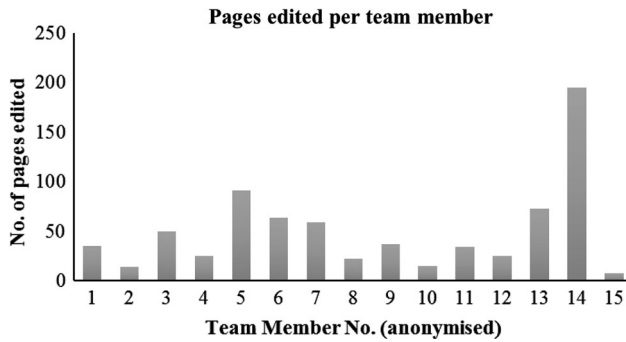
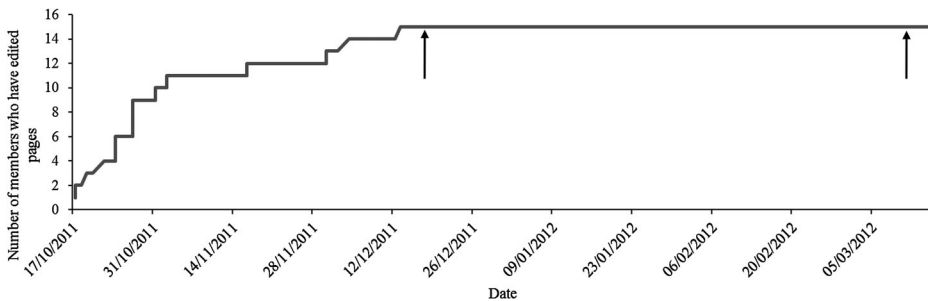**Figure 5.** Pages edited per team member.

Figure 6. Page edits over time to show when members of the team started using the wiki (arrows represent project assessment points).

highest number of contributions being 195 revisions (26%). The number of edits per team member is shown in Figure 5.

Figure 6 shows how the individual team members started contributing over time. After two weeks, 9 out of 15 members of the team were contributing. After two months (out of a 6-month project), all 15 of the team members were contributing. As can be seen from the graph shape, it may have been the assessment points (indicated by arrows) which stimulated the last members of the team to join in the activity.

A cumulative plot of page edits over time (Figure 7) shows that the page edits follow the work profile of the project: a gradual increase at first, then a steeper gradient before a major assessment point in mid-December, no edits over the holidays and a recommencement of the edits at the beginning of term, finishing steeply just before the final assessment point in mid-March.

A more detailed look at the contributions over time is shown in Figure 8. Each pattern represents a different member of the group. It can be seen that many members of the group are editing on the
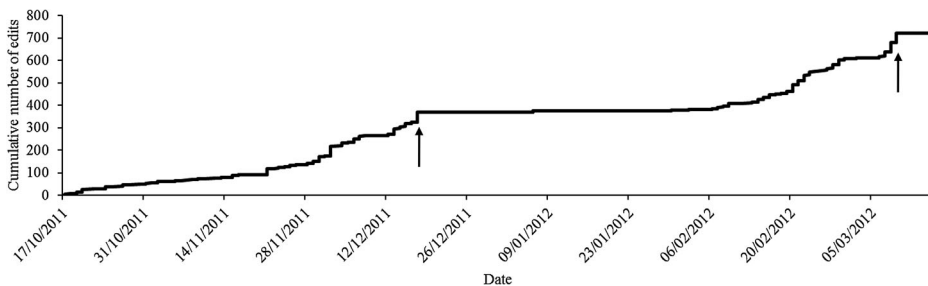

Figure 7. Cumulative page edits over time to show work profile (arrows represent project assessment points).
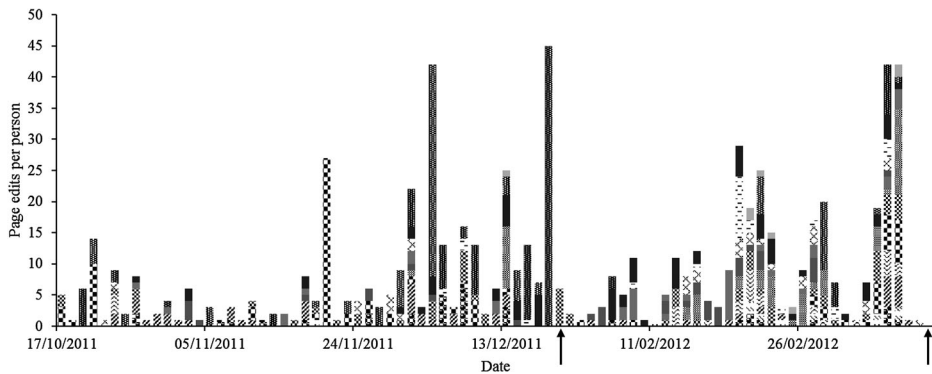
Figure 8. Page edits over time for spacecraft group wiki, each shade represents a different member of the group. Note that no edits were made from 18/12/11 to 30/1/12 due to holidays so this section has been removed (arrows represent project assessment points).

same days and this becomes increasingly common towards the end of the project. It is worth noting that one of the members of the group was extremely active on 16/11/11 and on 18/12/11, these dates being respectively, the day before an interim deadline, and the day before a major deadline. This team member may have thought, erroneously, that their wiki was being used in assessment or this may represent the increased collaboration necessary before a design finally comes together.

In terms of types of posts according to the categorisations devised in another study (Forte and Bruckman 2007), out of a choice of 'individual' or 'group' and 'editing', 'collaboration', 'reply' or 'content', over 90% of the Spacecraft case studies' contributions were related to 'content'. Interviews with the students were then performed to inform how the students used and experienced the wiki.

3.3. Results of interviews with students

Members of the spacecraft design team were asked whether they thought the use of the wiki enhanced communication and collaboration. One member of the group responded:

> The main function of the wiki was as a data repository, but small pieces of text to explain certain aspects of what document you were posting was very helpful. We also had some more general pages on group governance stuff (e.g.: meetings, emails etc.) which could be viewed quicker than if using Dropbox. You could also post links as well, this was useful.

Another student commented:

> The wiki was good at resolving disputes within the group as well as outlining the scope of the design. Many times a particular piece of work/ area of design may have had to hold until an answer had come through the wiki.

It appeared that the exercise of writing down thoughts and questions to other team members in the wiki helped the students. They also described how writing questions to other team members on the wiki helped allocate the responsibility of answering the question/resolving the issue to that team member.

When questioned why they might have engaged more than other groups, a member of the spacecraft design team stated:

> I believe we engaged in the wiki more than the other groups as most of the design process was new to us. We had only just started to study space systems and the design process was very different from aircraft, which the fixed wing groups would have been more comfortable with.

The lack of familiarity with the subject matter of the design challenge may have meant that the group was more open to new methods. Or it may have meant that they had a greater need to share information.

3.3. Comments and interaction on the wiki

Using Judd's content classification system (Judd, Kennedy, and Cropper 2010), in the case of the spacecraft wiki, almost 100% of the page edits were about content and were addressed to the group. They consisted typically of a document link, with a comment to explain it. For example, 'Orbit Maintenance Excel with Graph – orb. maintenance.xlsx (link to document)', 'Effect of Cerium doped coverglass on solar cells – Here (link to document)'. Although several students did attempt to inject some humour or friendliness in to their edits, for example, 'Welcome to the POWER subsection! You say What? we say Watt!' or 'Yo peeps, here is the new 3-view for your lovely reports'. However, it was also apparent that the wiki was helping the team communicate from afar, as one member prefaced an entry with: 'Hey guys, greetings from Sweden!'

4. Discussion

Up until the beginning of this study, students had previously communicated by having face-to-face meetings, sending each other documents via Facebook/email and storing them on a common drive using, for example, Dropbox. According to the survey, 16% of the students had already used a wiki. They also appeared to prefer to learn from each other than from the provided online materials. Academic advisors, who were provided with the same materials, did not engage with the wiki. Upon encouragement, two team academic advisors looked at the wiki from time to time, but did not use the commenting facility. Only one of the authors of this paper interacted actively with the wikis and questioned the students regularly. Fortunately, this was not critical to the success of the wiki rollout for the students, but was a weakness of this deployment and could be improved in future work by offering a hands-on introduction session to wikis and ongoing support for the academic advisors.

Overall, the first cohort of students perceived the wiki to be a useful tool, with 62% of the cohort agreeing or strongly agreeing that it enhanced collaboration. Other Blackboard tools such as file exchange folders and blogs were surveyed at the same time and did not receive favourable opinions, so it is assumed that the students felt comfortable enough in the survey to respond openly. Of the students who used the wiki at least weekly, 91% agreed/strongly agreed that the wiki aided collaboration. This connection between activity and perceived usefulness implies either those who use a wiki regularly are more likely to perceive it as useful for collaboration, or that those who perceive it as useful are more likely to regularly contribute. It was thought worthwhile to try the wiki for the next year, providing enhanced support via a skeleton wiki and more online guidance in response to the technical difficulties.

It is worthwhile discussing why some students in the first cohort may not have engaged with the wiki. Some hypotheses might include:

(a) They were not engaging in the overall project.
(b) As already mentioned in Section 3.1, they felt it was unnecessary for communication as they already had sufficiently close communication.
(c) They did not have the confidence to attempt to use a new tool. This is borne out by the fact that, of those who *had* used a wiki before, 67% used it at least weekly, compared to of those who *had not* used a wiki, 54% used it at least weekly.
(d) They came across technical problems and stopped. Eleven out of 57 students (19%) had technical problems with the wiki, according to the survey. In Section 3.1, students described a great variety of technical difficulties, with editing, updating, with the wiki being slow to load, Blackboard crashing, lack of ability to upload spreadsheets, etc. Of the 11 who had technical problems, 6 used it at least weekly and appeared to persist with it, thus implying that they were not dissuaded from using it by the problems. However, the other five may well have given up in the face of these difficulties.
(e) They did not prioritise the wiki, as it was not assessed.

(f) The group used an alternative. Despite strong guidance against using open file-sharing software, due to commercial sensitivity reasons, it is possible that some of the groups may have used the alternatives.

It was instructive to examine a case study from the second cohort: the spacecraft group. This group had the most comprehensive engagement with the wiki as indicated by consistent page editing over time. The team members were a mix of three disciplines and were motivated to work together as they had a complex task which required collaboration to solve. In terms of how they used the wiki to communicate with each other, it was apparent that they used it to post content and as a data repository. On their wiki they placed minutes of meetings, presentations, reports, spreadsheets and other design information. This group engaged with the task immediately and by the first deadline, all members of the group had contributed. This meant it was possible to see if any members of the group were contributing less or were delayed in their engagement. Had this been appropriate, the academic advisor could then have provided a discreet intervention. It was not planned to intervene in the teams as part of this study, merely to collect data to see if the contribution statistics could be useful. Within two weeks of the start of the project, multiple members were contributing on the same day regularly. The team members' individual contributions, as determined by page edits, ranged from 1% to 26% of their wiki.

The frequency of multiple edits on the same day showed high levels of engagement in the project by this particular team, although certain individuals contributed significantly more than others. These edits were not reacting directly to each other with comments, but each typically offered information critical to enabling the design to progress to the next stage. As previous studies have found (Judd, Kennedy, and Cropper 2010), the edits peaked shortly before the deadlines. But in this case, the build-up was a natural one, mirroring the workload the students were going through. There was no indication from timing or content that the wiki was constructed purely to conform to the course requirements. Interviews with the students indicated that they considered that it enhanced communication but did not replace face-to-face communication as they were having regular meetings anyway. It provided a way to communicate outside the meetings with contextual content, that is, commented information. It was not the purpose of this study to investigate the link between user contributions and quality of work, but to see what could be learned from the user contribution statistics. Equally it was not the purpose to focus negatively on individuals, but to aim to help groups function better as a team.

As the answers to the survey show, it would be overextending the results of the study to infer that those who do not contribute to the wiki were less engaged in the project. These participants may have been focusing on face-to-face communication, may have struggled with the technology or may have been prioritising their own individual design component to optimise their individual marks.

What is it possible to see from this data about team communication and engagement in a project? This study proposes that it is possible to:

- map the overall pattern of engagement of the team in the wiki and the timing of contributions, including whether this appears to be linked to assessment milestones or not.
- track individual team members' contributions to the wiki, including the number of contributions over time. This could be used to alert staff to those who might not be contributing to the project, although account needs to be taken of the possible alternative explanations for non-engagement in the wiki.
- categorise the content posted. For example, in the case study, 90% of the students' edits were related to 'content' which was addressed to the whole group, as opposed to commenting on other team members' work.

These authors suggest that the fact that commenting is not present, does not mean that communication is not happening. In engineering, commenting is commonly reserved for a specific point in the

design and is often performed by the customer or an independent team not involved in the original design. The type of inputs to the case study wiki would be categorised as 'content' by previous studies (Judd, Kennedy, and Cropper 2010), so whilst it was clear from the context of the comments that the team were collaborating, that is, 'working together to produce something' and 'handling inter-linked problems and subtasks', it was hard to infer this from the wiki statistical data.

The considerable engagement of the case study group in the wiki could be attributed to the behaviours and personalities of the team members, motivation from the academic advisor and a demanding and complex design challenge with interdependent subtasks. The spacecraft group knew that the author was looking at their wiki and may have believed that it was being assessed in some way. This erroneous belief may have influenced their engagement. The more frequent use of the wiki by the spacecraft team may have been a consequence of the encouragement of the academic advisor, or of team having more members so needing stronger lines of communication. It would be helpful to know whether this experiment, if repeated with different students and advisors, would yield similar results.

It would be interesting to be able to compare the design outcomes between groups which used the wiki extensively and those that did not. However, the design outcome is influenced by many factors, including the ability and engagement of the students in the team, the level of support provided by the academic and industry academic advisors and the complexity of the task. This varied between the spacecraft, rotary and fixed wing groups, so it was not possible to compare.

As stated previously, for engineering students, face-to-face communication in meetings is seen as the gold standard (Olson and Olson 2000). However, in engineering industry, telecons and emails often take the place of meetings. Unless encouraged to use wikis or other social software for team projects, students will not develop the skills to work in common virtual workspaces that they need for their careers.

5. Recommendations

Based on the experience of the authors of this paper, the following recommendations are made:

(1) Have a good reason for deploying wikis. Some of the design groups in this study were able to work so closely face-to-face that they felt that a wiki was not necessary for their communication.
(2) Consider carefully the particular wiki tool you use. The wiki used in this study was that deployed in the University's VLE and was not considered user-friendly by the students nor was it suited to easy upload of images and spreadsheets.
(3) Consider using a wiki in a prior project, as preparation for a more challenging one. To encourage participation, integrating the use of a wiki into a design task earlier in the curriculum is recommended.
(4) Provide training by human as well as online tutorials for using a wiki. Many of the students preferred to learn from their colleagues rather than the advisor or online.
(5) Do not forget to train and engage the staff who will be supervising. This was a weakness in this study.
(6) Provide a 'skeleton' wiki for students to populate. This worked well for the study's students and helped promote take-up of the wiki.
(7) Provide guidance for commenting. No comments were offered by students in these wiki projects and it is suggested that students would have benefitted from some guidance as to how to provide good comments and feedback.
(8) Look at and ask about the wiki as it progresses. Interest from the academic advisor is essential for engagement of the students. The groups in this study who participated most were also those who experienced most interest from the advisor.
(9) Provide prompt helpdesk support. Without immediate help from our Technology Enhanced Learning team to solve teething problems, the students would have given up on this project early on.

6. Future work

Building on this work, the authors intend to investigate how wiki metrics can be used to give an indication of the quality of collaboration in the group, that is, is the group displaying some or all of the behaviours displayed by teams successful at collaboration? This will draw on theoretical conceptualisations of collaboration and measures of effective collaboration used in the wider area of collaboration sciences. Another area of interest is to investigate further the relationship between an individual's or group's engagement in the wiki and the overall quality of their contribution. This could be done through linking marks from academic advisor and peer assessment and individual contributions to their individual wiki statistics. It would also be worth investigating whether some students deliberately limit their collaboration to focus on other aspects and to maximise their own individual marks.

As a separate piece of work, it would be interesting to assess other professional tools which could be used by Capstone teams to enhance their collaboration, like built-in Product Lifecycle Management in CAD systems and other concurrent design tools. These, combined with more 'social' tools such as the wiki, could provide better support for dispersed teams.

7. Conclusions

It is important for engineering students to develop the skills to communicate and collaborate with colleagues using common virtual workspaces for their future careers in the engineering industry. University Capstone team design projects are of a multidisciplinary nature and set at a level such that it is impossible to produce a good design without the team communication frequently and collaborating closely. They were thus a good vehicle for introducing a wiki to investigate its utility for communication, collaboration and the usefulness of user contribution statistics to assess student engagement in the project. Wikis were deployed in the University of Bristol Aerospace Engineering Capstone project from 2010 to 2012 with this purpose.

According to a survey performed at the end of the deployment of the wiki, 61% of the students agreed or strongly agreed that it enhanced collaboration. One particularly active group's wiki was used as a case study to investigate their use of the wiki. It was possible to monitor individual and team engagement in the wiki over time, so that the rate of working and effect of assessment deadlines were evident. It was also possible to see who was participating and if any team members were delayed in their participation in the wiki. This information, however, could not be linked directly to overall engagement in the project, as it was apparent that there were many other factors, such as problems with the technology or prioritising of individual work which could affect engagement.

The types of contribution were predominantly categorised as 'content addressed to the whole group' and little commenting occurred. Whilst it was clear from the contextual content of the wiki that collaboration was occurring, it was hard to infer this from any data. Recommendations and lessons learned have been provided for interested academic staff from other institutions. Wikis were found to be of limited use to investigate levels of communication and collaboration in this study, but may be of interest in other situations. Despite some drawbacks, wikis were considered a potentially useful tool to track engagement in virtual workspaces for Capstone Design projects in engineering subjects.

Acknowledgements

Disclosure statement

Notes on contributors

Dr Lucinda Berthoud has a Ph.D. in Space Physics from ISAE, Toulouse and an M.Eng in Mechanical Engineering from the University of Bristol. She has worked at the European Space Agency (1993–1995) and NASA Johnson Space Center (1997). From 1997 to 2003, she worked for the Spacecraft Systems Department at Airbus Defence and Space and since 2013 she has worked part-time for Thales Alenia Space as well as being a Senior Teaching Fellow at the University of Bristol. At UoB she teaches Systems Engineering, Space Systems and Advanced Space Systems courses on the Aerospace Engineering Degree. Her research interests are engineering education, interplanetary spacecraft design, nano-satellites and model-based systems engineering.

Joseph Gliddon has worked for six years as e-Learning Implementation Officer in the Technology Enhanced Learning team at University of Bristol, and previously worked for five years as the Virtual Learning Environments Manager at City of Bristol College. Prior to this he has worked as Visiting Lecturer, an IT Support Officer and in the private sector as an IT trainer. His research interests include collaborative social networks, learning design, cloud computing, content management, eReserves and video use in education.

References

Chao, Joseph. 2007. "Student Project Collaboration Using Wikis." *20th Conference on Software Engineering Education & Training* (*CSEET'07*), 255–261. IEEE. doi:10.1109/CSEET.2007.49.

Cole, Melissa. 2009. "Using Wiki Technology to Support Student Engagement: Lessons from the Trenches." *Computers & Education* 52 (1): 141–146. doi:10.1016/j.compedu.2008.07.003.

Curran, Richard, Xiaojia Zhao, and Wim J. C. Verhagen. 2015. "Concurrent Engineering and Integrated Aircraft Design." *Concurrent Engineering in the 21st Century: Foundations, Developments and Challenges, Springer International Publishing*, 571–605. doi:10.1007/978-3-319-13776-6_20.

De Pedro, X., M. Rieradevall, P. López, D. Sant, J. Piñol, L. Núñez, and M. Llobera. 2006. "Writing Documents Collaboratively in Higher Education Using Traditional vs. Wiki Methodology (II): QUANTITATIVE Results from a 2-Year Project Study." *The Fourth Congress of the International University Teaching and Innovation* (*IV CIDUI*). *Barcelona, Spain*, 10:2007. http://descartes.upc.es/cidui_2006/pujades/comunicaciones_completas/doc969.doc.

Elgort, Irina, Alastair G, Smith, and Janet Toland. 2008. "Is Wiki an Effective Platform for Group Course Work?" *Australasian Journal of Educational Technology* 24 (2): 195–210. doi:10.14742/ajet.v24i2.1222.

Forte, Andrea, and Amy Bruckman. 2007. "Constructing Text: Wiki as a Toolkit for (Collaborative?) Learning." *WikiSym 07 Proceedings of the 2007 International Symposium on Wikis*, 31–42. New York: ACM Press. doi:10.1145/1296951.1296955.

Jackson, Darla W. 2010. "Collaboration Versus Communication?: Selecting the Appropriate Tool." *Law Library Journal* 102 (2): 315–324.

Judd, Terry, Gregor Kennedy, and Simon Cropper. 2010. "Using Wikis for Collaborative Learning: Assessing Collaboration Through Contribution." *Australasian Journal of Educational Technology* 26 (3): 341–354. http://dx.doi.org/10.14742/ajet.1079.

Larusson, Johann Ari, and Richard Alterman. 2009. "Wikis to Support the 'Collaborative' Part of Collaborative Learning." *International Journal of Computer-Supported Collaborative Learning* 4 (4): 371–402. doi:10.1007/s11412-009-9076-6.

Marin, J. A., J. E. Armstrong, and J. L. Kays. 1999. "Elements of an Optimal Capstone Design Experience." *Journal of Engineering Education* 88 (1). http://onlinelibrary.wiley.com/doi/10.1002/j.2168-9830.1999.tb00405.x/abstract.

McLoughlin, Catherine, and Mark J. W. Lee. 2010. "Personalised and Self Regulated Learning in the Web 2.0 Era: International Exemplars of Innovative Pedagogy Using Social Software." *Australasian Journal of Educational Technology* 26 (1): 28–43. http://ascilite.org.au/ajet/submission/index.php/AJET/article/view/1100.

Nanda, Gaurav, Mark R. Lehto, and Shimon Y. Nof. 2014. "User Requirement Analysis for an Online Collaboration Tool for Senior Industrial Engineering Design Course." *Human Factors and Ergonomics in Manufacturing & Service Industries* 24 (5): 557–573. doi:10.1002/hfm.20551.

Olson, Judith, and Gary Olson. 2000. "Distance Matters." *Human Computer Interaction* 15 (2): 139–178. doi:10.1207/S15327051HCI1523_4.

Oxford University Press. 2015. "Oxford." *Oxforddictionaries.com*. http://www.oxforddictionaries.com/definition/english/.

Pinho-Lopes, Margarida, and Joaquim Macedo. 2016. "Project-Based Learning in Geotechnics: Cooperative Versus Collaborative Teamwork." *European Journal of Engineering Education* 41 (1): 70–90. doi:10.1080/03043797.2015.1056099.

Reinhold, Silvan. 2006. "WikiTrails." In *Proceedings of the 2006 International Symposium on Wikis - WikiSym '06*, 47. New York: ACM Press. doi:10.1145/1149453.1149467.

Schaffert, Sebastian, Diana Bischof, Tobias Bürger, Andreas Gruber, Wolf Hilzensauer, and Sandra Schaffert. 2006. "Learning with Semantic Wikis." *SemWiki2006, First Workshop on Semantic Wikis - From Wiki to Semantics, Proceedings, Co-Located with the ESWC2006, Budva, Montenegro, June 12, 2006*. http://www.researchgate.net/publication/220706621_Learning_with_Semantic_Wikis.

Schaffert, Sebastian, Andreas Gruber, and Rupert Westenthaler. 2005. "A Semantic Wiki for Collaborative Knowledge Formation." *Proceedings of SEMANTICS 2005 Conference*. Trauner Verlag, Vienna, Austria.

Smith, Matthew W., David W. Miller, and Sara Seager. 2011. "Enhancing Undergraduate Education in Aerospace Engineering and Planetary Sciences at MIT Through the Development of a CubeSat Mission." *Proceedings of SPIE, UV/Optical/IR Space Telescopes and Instruments: Innovative Technologies and Concepts V* 8146: 81460S-1. doi:10.1117/12.896130.

Todd, Robert H., and Spencer P. Magleby. 2005. "Elements of a Successful Capstone Course Considering the Needs of Stakeholders." *European Journal of Engineering Education* 30 (2): 203–214. doi:10.1080/03043790500087332.

Trentin, G. 2009. "Using a Wiki to Evaluate Individual Contribution to a Collaborative Learning Project." *Journal of Computer Assisted Learning* 25 (1): 43–55. doi:10.1111/j.1365-2729.2008.00276.x.

Appendix 1

Questions asked in an electronic survey performed at the end of the course for the first cohort.

1. Have you used a wiki before you started the project?

   Options: Yes, No

2. How often did you personally use the wiki as part of the project?

   Options: Less than once a month, Monthly, Weekly, More than once a week.

3. 'I found the wiki aided collaboration', please select which applies:

   Options: strongly agree, agree, neither agree nor disagree, disagree, strongly disagree.

4. Did you have any technical problems with the wiki?

   Options: Yes, No
   Further question: If yes, please elaborate.

5. In using the wiki, I found the following very helpful: advice from your group leader, online materials/videos, your own prior knowledge, the assistance of others in your group.

   Options for each: strongly agree, agree, neither agree nor disagree, disagree, strongly disagree.

6. Please use this area for any comments you had about the whole wiki process.