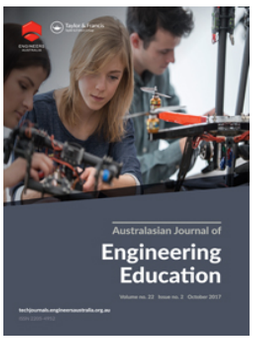

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MoodleNFC – integrating smart student ID cards with moodle for laboratory assessment

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ABSTRACT

Moodle (along with other Learning Management Systems), are widely used within the education sector to facilitate content delivery, marking and student feedback. This paper describes a system which is designed to significantly increase efficiency, accuracy, and security whilst reducing feedback latency for a laboratory marking environment. The MoodleNFC system described in this paper seeks to answer the question as to how to most efficiently record marks for students in a laboratory environment by considering aspects of efficiency, accuracy, data integrity and Moodle integration. For large laboratory environments the MoodleNFC system saves significant time by removing the need to search for and select the correct student requiring marking – instead a tutor simply scans a student's ID card which automatically brings up the student record. The system is evaluated based on measured improvements in efficiency, accuracy, and on evaluations completed by users of the system. Compared to a paper based marking system benchmarking has demonstrated that efficiency increases in the order of 50% are attainable.

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Electronic assessment; LMS; student feedback; laboratory marking

1. Introduction

Laboratories are a key component within modern engineering education. Laboratories provide students with a hands-on experience for synthesising the theoretical concepts and knowledge into concrete real-world examples (Feisel and Rosa 2005). Laboratories encourage students to analyse, measure, hypothesise and develop practical skills in ways that are difficult to perform using just lectures (Felder and Silverman 1988).

Some laboratories are being replaced by simulation activities or remote laboratories (where students remotely control real laboratory equipment). These alternatives have significant advances in scalability, cost and self-paced learning, leading to significant discussion related to the relative effectiveness and merits of different teaching modes (Gomes and Bogosyan 2009; Ma and Nickerson 2006).

Amidst all of these alternatives, most engineering courses still offer a significant proportion of laboratories in a traditional face-to-face format to offer rapid correction, instruction and safe supervision of operating procedures. In addition these laboratories allow students to use and manipulate real hardware which is more akin to the projected real-world scenario for a design engineer. This face-to-face contact also provides a significant opportunity for criterion referenced or achievement referenced marking (as it can be more difficult to assess a student's skill level and plagiarism based on a laboratory report) (McCabe 2005).

Many of these face-to-face laboratories use a paper-based signoff method where tutors sign off students as they complete key stages of a laboratory or perform observation-based criterion referenced marking (Perez-Hardy 2003; Sadler 2005). This sign-off marking approach allows flexibility for clarification of students understanding and even allows other competencies (e.g. oral communication or critical thinking) to be tested as students demonstrate these skills in explaining their work to the tutors.

This paper based marking approach has some significant problems related to administrative overhead, feedback timeliness, data accuracy and the facilitation of self-paced or laboratory exercises spanning multiple sessions.

With respect to administrative overhead, all of the marks need to be entered into a database to be compiled with other student records. With classes potentially containing hundreds of students, each with up to a dozen separate lab sign-off sheets, the task of timely, reliable data-entry becomes more apparent.

Timely feedback throughout a students' learning experience is a powerful tool which can be used to improve performance and understanding. At a process level (engaging in classroom activities during task acquisition), immediate feedback has been shown to be beneficial in improving student learning (Hattie and Timperley 2007). Hence, there is a need for not only entering data, but doing so in a timely manner.

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Data accuracy is also a significant concern. With the traditional paper-based system students data can be incorrectly entered, difficulties in reading handwriting, and students neglecting to record key details (their name/ID on marking sheets) along with paper-based sheets either sticking together or getting lost all lead to students missing out on marks they deserve. Paper-based systems also have an additional vulnerability where students could potentially forge/fake a tutors signature on signoff sheets resulting in them unduly receiving marks.

Finally, for laboratories spanning multiple timeslots paper management becomes a considerable issue as each student must locate their marking sheet from a pile of sheets which may span multiple labs.

One alternate marking management approach is direct marking through an LMS (Learning Management System). Although this approach fixes many of the issues prevalent in paper-based approaches (efficiency, vulnerabilities, accuracy) it can still take a significant amount of time to find student details – particularly for large class sizes or when students have very similar names.

This paper uses an approach based around NFC (Near Field Communications) to fix many of the problems as noted with the traditional laboratory marking approaches. NFC is a relatively recent innovation (about a decade) facilitating very-short range, half-duplex, wireless communication between devices (Coskun, Ozdenizci, and Ok 2015). NFC uses Amplitude Shift Keying (ASK) at 13.56 MHz to achieve data rates up to 424 Kb/s. The very short range (about 10 cm) is good for security in terms of snooping and packet captures and it also ensures that multiple devices can work in a relatively confined space (Ortiz 2006). Communication is typically performed using one of the operational modes shown in Figure 1. For the system presented in this paper, we use the reader/writer mode.

Many new smartphones and tablets are starting to come out with NFC which has enabled many different applications in an expanding domain area including access control, animal tracking, precision farming, financial (E-Payments), medical tracking, parcel tracking, transportation and position tracking (Khoury and Kamat 2009; Voulodimos et al. 2010; Welbourne et al. 2009). A common thread between each of these implementations is the need for reliable, unique electronic identification of a particular device (using an RFID/NFC tag). Within teaching environments NFC/RFID has been successfully used in attendance monitoring and library borrowing (Lim, Sim, and Mansor 2009; Bueno-Delgado et al. 2012; Benyó et al. 2012).

In this paper we present a system (MoodleNFC) which significantly improves the LMS based marking implementation in terms of efficiency and accuracy. The proposed implementation is designed for use on Android smartphones or tablets and uses NFC (Near Field Communication) to directly search for a student based on a scan of a student's ID card. This system has been integrated into Moodle and allows attendance recording, criterion referenced marking or task competency marking. Since MoodleNFC directly interacts

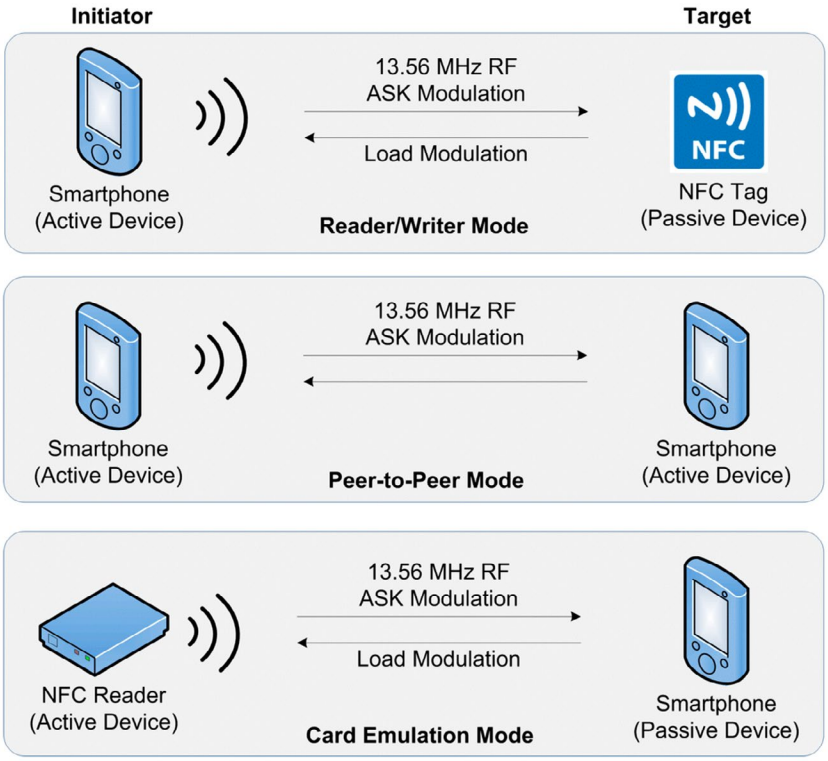

Figure 1. NFC Operating Modes (Coskun, Ozdenizci, and Ok 2015).

with LMS, it facilitates instant feedback to students on their progress through the subject.

The proposed MoodleNFC system also provides a significant advantage to assessors in providing detailed data which can be analysed to see what areas students are struggling with by separately recording and archiving data for each rubric. Although many paper-based systems involve rubric recording on paper, when the marks are entered into the database system often only a final mark is stored (for expediency) – which in the presence of such little data makes it difficult to determine what areas students are struggling with.

The MoodleNFC system described in this paper seeks to answer the question as to how to most efficiently record marks for students in a laboratory environment. The proposed system addresses four key criteria: efficiency, accuracy, data integrity and Moodle integration. Efficiency and accuracy factors are considerably improved with the removal of double handling, direct automatic selection of students and the use of a feedback loop where students can instantly verify their marks in their LMS. Integrity of the data is preserved with full tracking and traceability of all changes, the elimination of paper-based forgeries and the potential for data-mining of data with complete progress archival for all tasks for every student (along with metrics for all tutors which could be used for tutor benchmarking). Finally, direct Moodle integration was considered important to have a single marking repository and lead to the retirement of the predecessor system which required manual importing of marks into the Moodle LMS (Ross, Brown, and Torabi 2016).

The remainder of this paper is organised as follows: The System Overview section discusses the MoodleNFC system and presents the major functional blocks alongside highlighting the usability from the point of view of teaching staff. The Measureable Outcomes section outlines the performance metrics and measurement criteria used to evaluate the system. The performance of the system is then evaluated in the Results and Discussion section, with specific emphasis on the efficiency, accuracy and user acceptance. Concluding remarks then follow in the Conclusion.

2. System overview

This section provides an overview of the system architecture and implementation. Figure 2 shows the system architecture for the proposed MoodleNFC system. At a classroom level, all marking is performed through a smartphone or tablet which connects to the university WIFI network. The tablet or smartphone hardware used in the labs requires integrated NFC (Near Field Communication) to be able to read the NFC tags in each of the student cards. Based on availability, hardware cost and the inclusion of integrated NFC, Nexus 7 tablets and Nexus 5 smartphones were chosen as the platform of choice for the system. In practice these were found to be a robust and cost effective user interface.

The student cards issued to students have MIFARE Classic 1 K NfcA tags embedded within them. Though most of the card is encrypted and therefore unreadable on the Android system without specific encryption keys, the UID (a 4-byte unique card identifier field) is

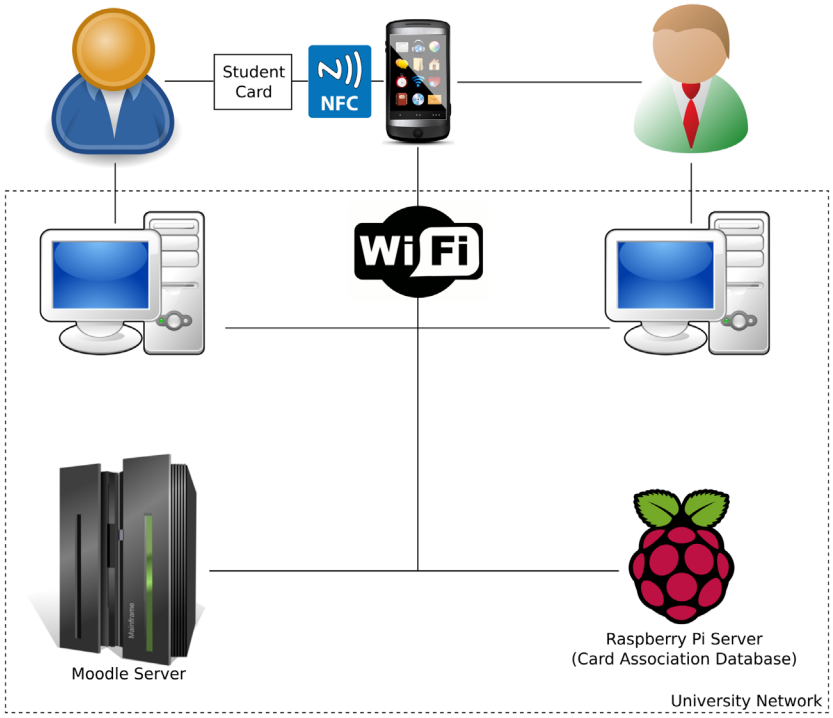

Figure 2. Top-level architecture of the proposed system.

readable and, as it is unique, is used as the means of card identification.

Both students and staff can directly login to Moodle (as normal) to view and/or change marks (based on their relative permissions). Additionally select staff are able to login to a management interface of the Card Association Database to update or change information. This management access is important if a student number is incorrectly entered (during the card association phase) and also when students have graduated to ensure that the database does not become excessively large containing redundant data.

One issue encountered with using NFC data to search for students within Moodle was the lack of a translation database which associates NFC tag UID values with actual student numbers. To solve this, a card association database was created to store the corresponding student number for each student card. The first time a student is marked off within the system the system detects there is not a record for the supplied card and the tutor is prompted to manually enter the student ID number.

The card association database is a local low-powered Raspberry Pi server running Apache and PHP. POST operations are used for all file uploads and only the relevant new records (a new student UID and ID number) are uploaded each time. This server is directly connected via Ethernet to the wired University Infrastructure network and has battery backup to ensure that recovery time is not an issue for brief power outages.

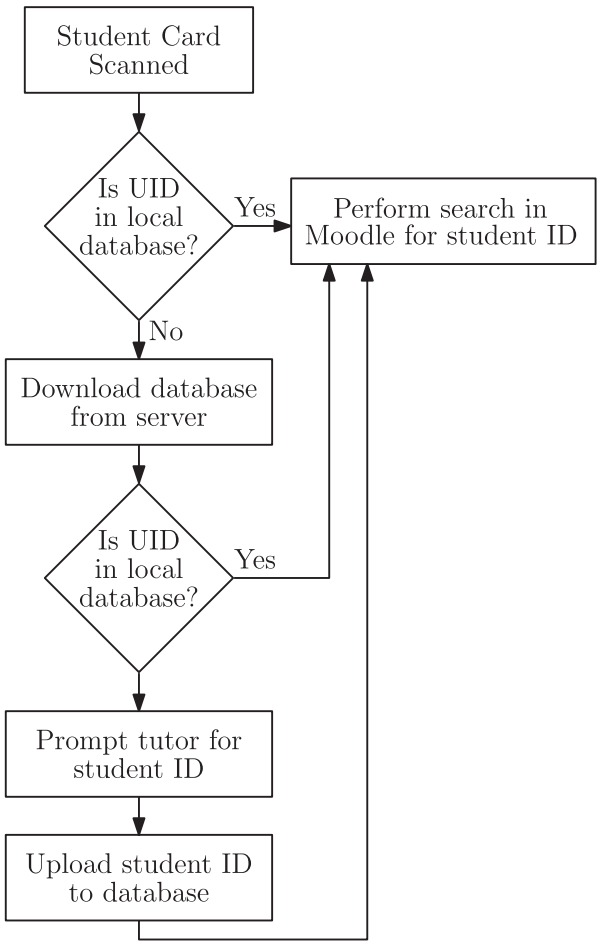

Figure 3. Flow diagram of card registration process.

It is important in terms of timesaving to ensure that the student ID can be searched as quickly as possible, hence, primary searching is performed on a copy of the database stored locally on the mobile device. When a match is not found, the first action is to download a new copy of the database from the server (in case another tutor has entered the student) before manual entry is prompted (as shown in Figure 3). When student card details are entered into the local database these are then immediately synchronised with the database stored on the server ensuring that all potential users have updated data.

Webview is used (Android OS) to provide a full screen web interface to allow users to directly login and interact with the Moodle Webpage. Within the Webview client the function *findAllAsync()* is used to search for the student number which has been looked up by the database. Data integrity within the Moodle Gradebook is maintained by regular backups and with all operations logged and stored as history.

Within Moodle, a criterion referenced rubric or competency of different sections within a laboratory task is represented in an assignment activity with a rubric grading method. This rubric grading method provides an intuitive, quick and customisable interface for tutors to supply marks to students (see Figure 4). Although tutors can manually search for a student, using NFC provides a rapid method of calling up a student's details from a list which may include hundreds of students (generally with quite a few sharing the same surname).

3. Measureable outcomes

The system was evaluated for efficiency, accuracy and user acceptance. For evaluating efficiency two separate benchmarks were constructed, one including the overhead of manually entering paper based student marks and the second the overhead of manually searching for a student on the LMS from a largle collection of students. Mark entry is considered for a class of 100 students and the time taken to enter marks for two separate tutors was evaluated.

For the manual mark entry student marks were provided on 100 separate sheets of paper which each needed to be entered into LMS on a PC. For the second benchmark, demonstrators used a tablet device to manually locate a student's record within LMS and then award marks to that student through a marking rubric. These benchmarks were compared to the time taken to scan a student card using NFC and enter the marks directly into the marking rubric.

To evaluate the accuracy, the allocated student marks were compared against ground-truth values both for data entry from paper hand-written based forms and for

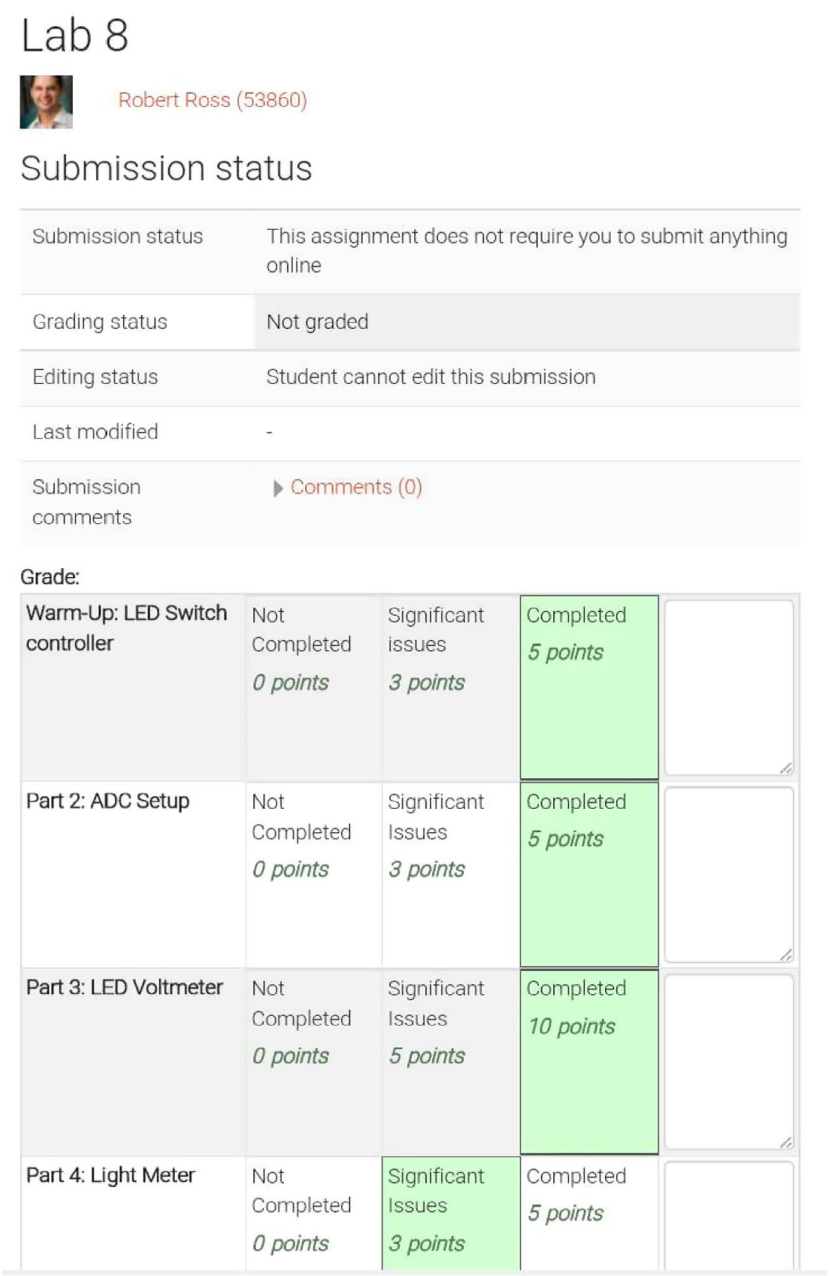

Figure 4. Screenshot of marking user interface within the MoodleNFC system.

traditional data entry directly into LMS from a mobile handset. For a realistic exercise several students had very similar names – making the process of choosing the correct student more difficult.

The current MoodleNFC system has been trialled for one semester across four subjects (1st year Engineering Design Project, 2nd year Microcontrollers, 3rd year Embedded Design and 5th year Embedded Processors) with respective class sizes of 180, 50, 40 and 50. Tutors from each of these subjects were presented with a survey at the conclusion of the subject to gauge the user acceptance of the system. The survey consisted of both quantitative (Likert style) and qualitative questions to gauge different aspects of the system performance. Additionally a student survey was performed to gauge student acceptance and feedback related to the system. Both of the surveys were conducted anonymously and were administered online as an element of the general subject feedback provided within subjects. This student survey included both quantitative Likert questions and open-ended feedback questions. The student survey was completed by 11.3% of all eligible students (in the target subjects) whilst 86% of the relevant tutors filled out the tutors survey.

4. Results and discussion

The MoodleNFC system has been evaluated using three different means:

- Comparative benchmarking analysis
- Staff survey
- Student survey

These evaluation methods gauge the user acceptance of the system and quantify the efficiency and accuracy gains related to the implementation of the system. Table 1 summarises the results of the benchmarking activity.

In terms of efficiency, the MoodleNFC system has an efficiency gain of 48% over the paper based entry and 31% over the manual LMS searching technique. The majority of the time spent with the MoodleNFC system was waiting for the page to load (must be done 3 times) when a student record is selected and updated.

Different challenges (including reading handwriting) and differentiating between students with similar names were specific issues which were found with the paper based system slowing the data entry process. Additional time would be spent for the paper based approach for labs that are operating over several weeks where students need to try and find their marking sheets from a class set.

Likewise, with the manual LMS searching technique, finding the student's name amongst a large class list and ensuring the correct student is selected reduces efficiency. The manual searching techniques would have been slower in reality as the benchmarks were based on reading a student's name (not trying to remember a student's name as would be done in a realistic class environment). Hence, for a class of 100 students, completing a total of 12 laboratories in a semester, using the MoodleNFC system would save 6 h and 2.8 h over the paper based entry and manual LMS searching techniques respectively.

The accuracy of the MoodleNFC system is the highest of the benchmarks as, by design, an incorrect student cannot be awarded marks. The errors in the paper based entry were tracked down to 1 transcription error (where the wrong number was entered) and one paper sheet that was not entered (it was later found in the pile but in a class environment would have been missed). The single error discovered when performing manual LMS searching was a simple data entry error for an individual student (an incorrect mark was assigned to the correct student). This mark assignment error is still possible with MoodleNFC but is expected to be less prevalent as the operator workload is reduced (in student selection) and students can directly observe the marking process to provide direct feedback.

A total of 6 tutors filled out the survey, constituting 86% of the tutors using the MoodleNFC system for the trial subjects. The quantitative survey results are summarised in Table 2.

Questions 4 and 5 compared the MoodleNFC system to relevant alternative in-lab marking systems. Respondents scored the MoodleNFC system very highly compared to the alternatives, particularly paper based marking which in the past has proven to be cumbersome from a user's point of view.

Table 1. Benchmarking results of the MoodleNFC system with paper based entry and manual LMS search entry.

Benchmark scenario	Mean time per student	Accuracy
Paper based entry	37.8s	98.8%
Manual LMS searching	38.3s	99.8%
MoodleNFC	19.6s	100%

As increasing efficiency was one of the key driving factors behind the implementation of the MoodleNFC system, it is good that respondents recognise the time-saving nature of the system (as was shown in the benchmarking activity) with responses to Question 1 at 4.67.

Questions 2 and 3 are related to the reliability and accuracy facilitated by the system. The system reliability ranked very high (4.00), but was attenuated by two predominate factors. Early in the first semester of use there were some teething problems relating to some versions of the Android operating system preventing NFC from scanning – these were quickly remedied with a new release which has proven very reliable. Secondly, the system is very dependent on quality WiFi and LMS performance. As the WiFi access points in the labs where the system is predominately used have been recently upgraded this is much less of a problem than they were for the previous online lab marking system.

Respondents were very confident in the accuracy of the system with a score of 4.83. This high measure of confidence can be attributed to the guarantee that the correct students will be assigned marks and the instant feedback that is provided to students to allow them to check their marks and identify any perceived discrepancies.

Questions 6 and 7 focus on the student experience of the MoodleNFC system. These both rated very highly with high praise for the concept and a very positive student response to the technology, particularly when they realise they can directly view feedback on their marks through the Moodle interface.

One lecturer commented that, since using the MoodleNFC system: 'It is hard to put a figure on it, but I believe my marking time including collating all the marks has reduced by more than half.' This estimation correlates strongly with the benchmarking results of efficiency increases in the order of 50%.

An optional, anonymous student survey was also conducted and received responses from a representative group of 11.3% of the student cohort from years 1–3 for students who were using the MoodleNFC system in laboratories. The responses from the survey are tabulated in Table 3.

Questions 1, 3 and 4 highlight the positively received educational outcomes of the MoodleNFC system. Question 1 (with a high score of 4.38) highlights the importance of timely feedback that students are given through Moodle (where marks are instantly available for view). In free text fields some students commented that greater granularity (i.e. more marking divisions) or text based feedback be provided – this is possible in the

Table 2. Quantitative Likert results of staff survey on a scale of 1 to 5, where 1 corresponds to 'Strongly Disagree' and 5 corresponds to 'Strongly Agree'.

Question	Result
1. MoodleNFC saves me time	4.67
2. MoodleNFC operates reliably	4.00
3. MoodleNFC makes me confident on the accuracy of marking	4.83
4. MoodleNFC is significantly better than traditional LMS marking	4.67
5. MoodleNFC is significantly better than traditional paper based marking	4.83
6. MoodleNFC facilitates self-paced learning	4.67
7. The student response that I have witnessed related to MoodleNFC has been positive	4.17
8. I like the concept of the MoodleNFC system	5.00

Table 3. Quantitative Likert results of student survey on a scale of 1 to 5, where 1 corresponds to 'Strongly Disagree' and 5 corresponds to 'Strongly Agree'.

Question	Result
1. The MoodleNFC gives me good feedback on my progress	4.38
2. In my experience the MoodleNFC system has operated reliably	4.33
3. MoodleNFC makes me confident that I will get the marks I deserve	4.20
4. MoodleNFC is good for self-paced learning (allowing me to catch-up on labs or complete different labs)	4.14
5. MoodleNFC is significantly better than traditional paper based marking	4.29
6. I'm impressed by the concept and use of the MoodleNFC system	4.14
7. I would like to see MoodleNFC used in more of my subjects	4.20

system simply requiring lecturers to slightly adjust the way they create the lab marking section in Moodle. For Question 3, students also ranked the system highly in terms of giving them a mark they deserve. This high level of student trust is facilitated as they form part of a feedback loop where they can check and query their marks at any time so that any perceived discrepancies can be cleared up.

Question 4 relates to the use of MoodleNFC for self-paced learning. Many laboratory classes allow students to work with semi-autonomy and complete significant amounts of work outside of class. Students rated this highly, but not quite as highly as some of the other sections. Typically for these self-paced activities a rule is in place that students must not be more than 1 week behind the prescribed material (to mitigate against students unnecessarily falling too far behind).

Questions 2 and 5 focus on the students perception of the system performance. In terms of reliability, there have been very few reliability issues, as student records are maintained through the Moodle system and apart from Moodle and WiFi outages (which are very rare during teaching hours) the system continues on operating as normal. Likewise the MoodleNFC system ranks highly compared to a paper-based system (Question 5). This figure would be expected to be even higher if the students had significant exposure to paper based marking or were responsible for collating paper based results.

Questions 6 and 7 relate to the student acceptance of the MoodleNFC system. These both rated very highly with students very impressed by the concept of the system and the ultimate test – a desire for it to be rolled out into other subjects (as is currently happening).

Within the survey, students were given the opportunity to suggest enhancements and address concerns they had with the MoodleNFC system. The major suggestions could be categorised as: providing additional granularity in the feedback (the granularity is specified by the teaching staff to whatever level they wish) and include an aggregate of student marks across the class for students to benchmark themselves on (another feature which can be implemented within Moodle).

Survey recipients were also provided with a free-text field to provide any additional comments or clarifications of previous questions. The comments were overwhelmingly supportive, with two in particular which stood out in highlighting the student's support behind the MoodleNFC system:

> This system is absolutely amazing. Initially, I got astounded with the way you were marking for the Labs. I strongly agree that this should be implemented for all other labs too. This type of system boosts up the zeal to do the laboratories. Rather than procrastinating the lab work and understanding nothing, this system helps us to be punctual and at the same time we are able to get marking. Creating lab reports gets little bit tedious. Thanks to this system. No lab reports plus better understanding of the concepts.

> I value that the MoodleNFC system lets me quickly see my marks for a lab, with a detailed description for each mark in each section, instead of just giving me a total percentage mark.

Based on the very positive feedback from system users and the significant enhancements in both accuracy and speed, the more widespread adoption across the engineering department and across the University is expected over the next 12 months. Current interest has been seen from fields as diverse as arts, computer science and microbiology.

5. Conclusion

In this paper we have described and evaluated a more efficient, accurate, secure means of recording marks for students in a laboratory environment. We described the architecture and functionality of MoodleNFC – a system that integrates NFC technology with Moodle to improve marking efficiency, accuracy and feedback time for laboratory environments. The system uses NFC enabled Android tablets and phones to scan student ID cards to quickly navigate between students in Moodle for rapid marking or attendance recording. The MoodleNFC system was evaluated based on benchmarking (shown to increase efficiency in the order of 50%) and survey results from tutors and students. MoodleNFC was evaluated across four subjects in the Engineering Department, and

is currently being more widely adopted across several departments. The system has been shown to significantly improve laboratory administration – removing manual data entry, slow electronic entry, delays to receive marks along with lost, forged and illegible marking sheets. One future enhancement we envisage for this system is functionality to use NFC for directly taking attendance into an LMS attendance module to provide a rapid, secure means of record keeping.

Disclosure statement

No potential conflict of interest was reported by the author.

Notes on contributors

Robert Ross received B.EE, B.CS and PhD degrees all from La Trobe University, Melbourne, Australia in 2007, 2007 and 2013, respectively. Robert is currently a senior lecturer with the Engineering Department, the director of the RAMPS (Robotics, Automation, Mechatronics, Prototyping and Sensing) R&D Team and has been actively involved in research into sensors, robotics, machine vision and innovative marking systems to facilitate laboratory development and marking.

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