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Requirement Engineering for Effective Mobile Learning: Modelling Mobile Device Technologies Integration for Alignment with Strategic Policies in Learning Establishments

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Abstract—In spite of several efforts in the last decade by researchers and educators, expected potential from the use of mobile device technology (MDT) to effect learning transformation is largely unfulfilled. Quantifying benefits of MDTs in learning, either through achievement of learning objectives or enhancement of the process, remains problematic. Rapid changes in development and manufacture also continue to present additional challenges. Most trials typically employ use case approach of evidencing benefits through usage experience. In this paper, application of Requirement Engineering (RE) methodologies to specify goals and requirements for mobile learning (ML) is proposed. Alignment with teaching and learning strategies as well as other institutional goals and strategies will be essential for successful integration of MDTs in learning. RE techniques can be used to achieve this. Finally, a case study is presented to illustrate the use of some of the approaches proposed.

I. Introduction

IN recent past, educational communities have appropriated available innovative technologies to enhance learning and transform the system. This has led into the coining of the discipline "educational technology", concerned with the effective facilitation of e-learning and technologies in learning. Technology appropriation has itself become a discipline of sorts, a way of exploring the impact of a given technology on a community or the society at large [1]. In spite of efforts with often mixed results, the community remain on the left foot forward; playing catch-up as advances in technology break moulds, making previously innovative ideas obsolete even before they have begun to take shape.

With increasingly powerful computing capabilities and affordance of convergence between multiple devices such as audio, video, camera etc., MDTs are transforming societal constructs and interactions. Businesses take advantage of advances to streamline their business operations; individuals, groups and communities use them to augment their life styles and coordinate relationships. The society as we know it in this generation is rapidly changing as a result [2], [3].

Within the modern UK educational sector, students admit to using devices to facilitate access to learning and for personal development but see no sustained use in most of their learning sessions and classrooms. Some educators confess they have no clue about precise benefits to learning or how this may be applicable to their teaching practice. Many schools and Further Education (FE) colleges impose an outright ban on the use of mobile devices by students within school premises, believing they are disruptive and problematic for classroom management. Many Higher Educational Institutions (HEIs) have implemented Bring Your Own Device (BYOD) schemes as part of their IT support provision strategies without fully exploring support, privacy and security issues [4], [5], [6].

The UK government is not left out in efforts to facilitate mobile device usage and information mobility in the society. Robust internet and WiFi connectivity is part of the policy strategies of the current government [7]. JANET, the body responsible for providing free public access to WiFi for FE and HE (Higher Education) establish a partnership with BskyB's The Cloud, "one of the UK's leading public WiFi providers" in November 2013, ensuring free and robust service for "over 18 million end-users in UK research and educational sector [8]. Interestingly, some of the staff respondents to a mobile learning research conducted in schools and FE colleges admit they either have zero or very little support to connect or are unsure of how to use them in teaching and learning practices in a mobile learning study conducted recently.

In some respects, BYOD schemes are sometimes little more than strategic ploys to minimise infrastructure costs while ensuring they are competitive in their provisions without really addressing underlying problems. And many support staffs admit they are struggling to support some of the less common or recently released devices. Many also feel they are unequipped or unsupported by the organisation; with no training and / or expert support knowledgebase [9].

The almost 'lightning-speed' pace of advances in MDTs continue to present both potentials and challenges. Previously innovative instructional designs become obsolete almost as soon as implemented. Yet, many remain in use for years well beyond use-by dates. Regardless, some would say mobile learning is here to stay. Others would add, perhaps cynically, that there is no evidence of actual learning involved in some efforts, the devices used primarily for access and delivery only for the most part [10], [11].

In this paper, it is proposed that application of domain neutral Requirement Engineering (RE) techniques may provide more insights into these problems, and perhaps help align business goals and requirements. Preliminary work relating to the use of RE techniques to explore current issues in mobile learning (ML) and the relationship between MDTs and education is first presented, followed by a case study illustrating some of the approaches proposed.

II. Engineering the Current Reality

Reference [12, pp. 7] defines Requirement Engineering (RE) as "a set of activities concerned with identifying and communicating the purpose of a software-intensive system". Software-intensive systems are described as systems comprising of some form of hardware or networked components, and involving human interactions and activities. Reference [12, pp. 3] added that RE "provides a framework for understanding the purpose of a system and the contexts in which it will be used", bridging "the gap between an initial vague recognition that there is some problem ... to building a system to address the problem".

Another definition for RE proposed in the year 2000 by [13] stated its suitability for specifying what the authors called "real-world goals" i.e. reflecting the tendency for change in the real world. More recently, [14, pp. 42] agrees, adding that "each RE process starts with an aim to change the current reality". The author stated all software systems are used within a context, adding that while system goals may be clearly defined, quite often variables within the context are not so clear. The latter may explain the rationale for a look to RE methodologies for ML systems. Although not strictly software-intensive applications but many interconnecting systems and technologies; the very nature of the system make it a likely domain for the application of RE.

Mobile devices have progressed from voice communication tools into computerised devices that not only enables easy collaborations between geographically dispersed individuals, but those also creating convergences between multiple media devices. Crucially, they are also providing means of connecting varieties of systems in ever increasingly complex contexts. For the sake of simplicity, these technologies will be referred to in this paper collectively as "mobile device technologies" or MDTs; encompassing mobile devices, convergence affordability, communication channels, remote, local and wireless network connectivity etc. Usage context is that relating to learning establishments, and HEIs in particular.

III. Requirements Engineering Techniques Selection

According to [15], there is no one prescriptive way of applying RE techniques to a system but the authors caution on ensuring techniques are applied early in the system lifecycle. With so many to choose from, techniques will largely depend on the system goal and contexts. A major weakness found in many is their complexity and lack of clarity, making them unusable by anyone but experts in RE or software engineering techniques [16].

Regardless, many authors agree the following core stages are essential in RE [15], [17], [18]:

- Inception and elicitation
- Identification, analysis and negotiation
- System modelling and goal specification
- System validation, risk and change management

Some of the activities involved in each of these stages will be discussed next.

A. Elicitation of needs

The bulk of the fact finding process in RE is usually in the inception and elicitation phase. However, elicitation is also a task that will continue throughout the life of the project and beyond system implementation. For example, whenever changes are made to a system, requirements for those changes have to be re-evaluated [18], [19]. Reference [18] cautioned that not all the information obtained would become requirements. Some needs may not be feasible to implement in the final product.

There are several stakeholders with potential input into the ML system including device manufacturers, educators, students, policy makers and those in the role of learning support and governance. While device manufactures may not be particularly interested in prioritising the needs of the educational community at the exclusion of others, they are likely to be concerned if their product(s) are unusable by members within the community. If the device is overly complicated then consumers, who may also be students and / or educators will not want them. Device manufactures may also be concerned about policies preventing freedom of usage in learning establishments.

Educators are often keen to appropriate technology that would make their practice more effective and achieve learning objectives. They are however unlikely to want to give up too much of their time for pedagogic and instructional design. In the same way, students may have devices but unable to use them effectively for learning. Seamless usage may also be problematic because the necessary connections and support are not adequate or robust enough, or there may be policies prohibiting use [20].

For learning providers, as may be true also for educators and students, running cost is still an issue. Costs may also include provision of ongoing technical support by the institution. Interoperability with other applications on the local network systems will be essential and ensuring the environment is rich enough to support such levels of inter-connectivity may be beyond sustainable budgeting strategies. And while mobile devices include tablets / devices with wide screens, powerful media support features and educational affordances, there are many with less than satisfactory experience still. It is believed this will increasingly become less of an issue [10].

Personal preference and cultural perceptions will also play a key role in intentions to use. For instance, in the past majority of consumers are uncomfortable conducting financial transactions on mobile devices. Today, the number is growing despite persisting security concerns [21]. Possibilities of cyber bullying and abuse are other issues among others. In a research conducted recently, a group of staff and students in an HEI stated of mobile devices: "can cause epilepsy – when it does not work", "too dangerous" and "very dis-humanising". These statements may illustrate extreme opinions held by some stakeholders still. Thus, these and other concerns must be elicited carefully. It is also important to identify sub-groups within each stakeholder groups with potentially differing opinions. For example, educators group may include tutors or pre-service tutors who may also be students themselves in HE. Reference [22] called this purposive sampling; describing the conscious inclusion (and exclusion, as well as the contextual grouping) of certain groups of participants.

Techniques used in elicitation may typically be employed in other RE stages including those for eliciting and analysing goals for the system, which [18] suggest is sometimes overlooked but an important part of fact finding. Establishing goals may in fact aid requirement analysis and can be analysed using goal modelling. One of the more commonly known goal modelling techniques is referred to as KAOS (Keep All Objectives Satisfied) [18], [23] citing [24], [6]. KAOS specify the use of verbs as well as AND / OR operators to link goals to processes [25]. Goal modelling will be discussed and illustrated more in subsequent sections.

Other elicitation techniques include ethnographical research methods [15]. Ethnography is an exploration of the community concerned and the cultural contexts using quantitative methods such as surveys; and qualitative methods such as observations, interviews and focus group studies. In this manner, interests and the emotional appeal of components within the system or the product being developed can be measured [18]. Brainstorming and prototyping may also be employed during the elicitation stage.

B. Identification, analysis and negotiation

This is a logical stage following directly or conducted in parallel with the elicitation of requirements. Information obtained from stakeholders need to be analysed, categorised and ranked. What are the current and new requirements? Who are those involved and where are they located? What are priorities for the business or organisation, and what are the conflicts? Conflicting requirements or potential problems must be identified and resolution decided.

Stakeholder agreement on the goals and requirements could be difficult to obtain without negotiation. Alternative options and acceptable compromises must be presented to resolve complex dissensions and disagreements on requirements and / or goals. Identifying and phrasing the most important goals for the system in terms all stakeholders can agree with and understand, may also be useful [17].

Establishing agreement on root problems can be problematic as in the ML system. Many of the stakeholders may be steeped in blame culture, making buy-in from stakeholders difficult. Even when buy-in is assured, having input from several groups of stakeholders may present a problem for the study. Reference [26] suggest the use of trade-offs adding that it is impossible to satisfy all the requirements by one specification quite often; usually typical of non-functional requirements. An example of trade-off analysis for the ML system can be seen in Table 1. The table shows strengths in opinions and level of importance by doubling or tripling certain symbols.

Reference [18] propose negotiations and brainstorming in several scheduled Quality Attribute Workshops (QAWs). In QAWs, the facilitator creates a Quality Attribute Scenario (QAS) for each of the concerns expressed by a stakeholder. Each stakeholder can express two or more of their most important concerns. The QAS is presented to the group and a handful is selected and debated. Finally, the facilitator supports the group to identify important requirements to be included in the system.

Another potential problem could arise from volatility in functionalities and the increasingly convergence nature of MDTs. Establishing meaning and interpretations of requirements may be difficult, or worse impossible if device features keep changing [18]. Some level of stability may need to be assumed or achieved. Other techniques employed may include prototyping, global analysis, focus group, requirement analysis and release planning [27], [28].

C. System modelling and goal specification

Modelling is an essential RE technique often used to analyse requirements as well as goals at various stages throughout the process lifecycle. Some of the more commonly used modelling techniques are listed below [18]:

- **Artefact modelling:** Used to define the work products and interdependencies and to specify maintenance requirements for processes.
- **Goal-oriented modelling:** Concerning the needs and vision of the business organisation and not necessarily the customers or users of the service(s) or system products.
- **Model-driven RE (MDRE):** Model-driven requirement engineering is typically used for large complex systems and can span the project lifecycle, from inception through to maintenance.

Other modelling techniques used in RE include **feature** and **process** modelling, typically used during the elicitation phase. In Sections IV and V, modelling techniques applicable to the ML system are illustrated in more details.

D. System validation, risk and change management

During this stage system model(s) and specification are evaluated against requirements and agreed. Validation process can often be the most complicated part of RE, resulting in inability to reach a consensus agreement, especially where different stakeholders with conflicting opinions and goals are involved. Risks to the system are identified and measures established to minimise their effect on future optimum performance of the system and to manage changes.

Reference [13, pp. 6] warns, "If stakeholders do not agree with the choice of problem frame, it is unlikely that they will ever agree with any statement of the requirements". The authors suggest a resolution may be to promote an agreement "without necessarily making the goals explicit"; in other words, rephrasing goals and requirements using terms that may be more moderate than specific.

Several RE methods have been suggested for investigating ML and similar systems, and for aligning the goals of the system with learning / business strategies. In the next two sections, categorizing and modelling techniques are explored in more details. A case study using goal modelling to specify some goals for the system is next presented. Information used in the goal model will be extracted from corporate and operational strategies of a UK HEI, demonstrating how alignment may be more easily achieved.

IV. GOALS FOR MOBILE LEARNING (ML)

Information obtained during elicitation needs to be organised, ranked and / or categorised in order to identify them as either goals or requirements of the system. This can often be complicated by the many different classification techniques available in RE. Again, the technique chosen will depend on the objectives for the system and the type of information to be analysed.

Some authors suggest goal analysis and specification is one of the methods that should be used more carefully and prioritised [29], [25]. Both of these authors believe that while many appreciate its importance, it is often side-lined in literature and formal specifications for the system. Goals are well understood to be the objectives or targets to be satisfied by the system under development, and they may often be explicitly presented to system engineers by stakeholders at project inception. The assumption then, that a formal specification for achieving those goals is all that's required may account for the oversight. Reference [25] refer to this as the "top-down" approach [pp. 3].

For [18] and [25], the initial set of goals is just the beginning of goal development process; an important basis on which to continue further analysis and refinement. Reference [25] believes that will require asking the 'HOW' and 'WHY' questions [pp. 3]. Thus, goal elicitation continues alongside establishment and elicitation of needs. Conflicts and problems are identified and resolved. New features or changes in the system will require alterations or modifications. New goals may also arise from validation, risk and change management processes [25], [18].

Goal modelling is sometimes seen as a discipline of sorts and also referred to as Goal-Oriented Requirement Engineering (GORE). This section outlines some strategies used in GORE, which may be employed throughout a project lifecycle during RE stages explored in the previous sections.

A. Classification of goals & requirements

An explicit set of goals or strategies for ML and the integration of MDTs in learning are sometimes missing from teaching and learning strategies. Many institutions would often specify a goal for technology infrastructure provision and support, of which it is assumed technologies supporting ML may be a part. It is proposed in this paper that a specification is necessary to move the agenda forward. This may be explicit or inferred from other goals or strategies. Unfortunately, such considerations have so far been glaringly omitted in past and current ML implementations and literatures.

Goals and requirements for a system may sometimes be classified as **soft** or **hard**. Soft goals describe objectives that are more 'desirable', less precise and therefore subjective; while hard goals are usually specific. Consequently, hard

TABLE I.
A SUB-SET OF TRADE-OFF ANALYSIS TABLE FOR A MOBILE LEARNING SYSTEM

	Functional requirements / stakeholders						Non-functional requirements (NFRs)*		
Goals	Students	Educators	Learning support	Governance	Government / global educational policies / acts	Device manufacturers	Pedagogic	Learning enhancement	Usability
Provide MDT accessible platform interface	✓✓✓	✓	✓	✓✓✓	✓	-	+	+	++
Provide assessments & diagnostics to support ML plans	✓✓✓	-	✓✓✓	✓	✓	-	++	+	+
Provide MDT customisable interface features	✓	✓	✓	-	✓	-			++
Provide MDT lesson planning and management features	-	✓✓✓	-	-	✓✓	-	++	+	
Provide MDT navigation & search functionality in resources	✓✓✓	-	✓✓	-	-	-			++
Provide MDT personalisation learning experience features	✓✓✓	-	-	✓✓	✓✓	-		++	++
Integrate MDT resources and / or activities	✓✓✓	✓✓✓	✓✓✓	✓✓✓	-	✓✓			++
Integrate MDT resource metadata harvesting features	✓✓	✓	✓✓✓	✓✓✓	-	-			++
Prevent integration with social networking sites	--	✓✓✓	-	-	-	-			

** Other non-functional requirements may include security, availability, etc. [14]*
Strengths or level of importance is signified by doubling or tripling of some symbols

Key
Ticks (✓): Prioritisation for stakeholder group
Dash (-): Neutral stand
Double dash (--): Disapproval, conflict or concerns
Plus (+): Relationship between goals and NFRs

goals are sometimes also referred to as functional specifications for the system. For example, specifying requirements for obtaining an educational qualification, 'passing the assessment examination' may be a "hard" goal / requirement but 'passing the assessment examination with distinctions' is not. 'Passing' is required but 'passing with distinction' can only be classified as a 'soft" goal [30], [31]. Therefore, at the top-level, most goals and requirements can be categorised into functional or non-functional. Functional requirements represent functions or actions that the system or part of the system must perform while non-functional requirements are those that measure how well those functions have been performed. While this categorisation is well suited to systems resulting in an end-product, it can be possible to miss other variances within some systems if they are not classified further and the ML system may be an example.

When the root problems in a system have not been established or agreed by stakeholder groups, goals are often unclear and subjective. RE techniques used must therefore be able to not only identify the root problems and specify requirements, but also specify goals for the system. Identifying the factors, issues and strategies within the system may be more relevant in this case. They are also particularly suited for classifying soft goals and requirements, especially those that are subject to many interpretations. It is also possible to develop use cases that can be used in testing the system from developed use case scenarios, which can be generated from the factors [32].

B. Factors, issues and strategies

Factors, issues and strategies are techniques used in global analysis; an RE methodology used to categorise "soft" goals and requirements that may not quite fit well into the functional / non-functional categorisation [30]. Reference [25] defines these as those whose "satisfaction cannot be established in a clear-cut sense"; as opposed to "hard" or requirements "goals whose satisfaction can be established through verification techniques" [pp. 3]. Global analysis is particularly suited to systems that need to be examined from several perspectives and involving many different groups of stakeholders.

Another advantage is that they can help in addressing concerns and barriers within the system when used early in the elicitation process. Classifying all the information gathered during global analysis into factors, issues and strategies may also simplify the ranking process, making it easier to prioritise goals and requirements for the system.

Factors are different from requirements, in that they do not exactly describe the system but may relate to the context or a component of the system. For example, a student stakeholder stated "I have a Blackberry but I can't use it properly and I can't sync it with my MacBook"; relating to the effective working of part of the system and achievement of the goals rather than a requirement of the system. The statement reveals a few factors:

- Synchronisation with a PC / laptop is a desired requirement.
- Some devices (e.g. Blackberry) may not sync properly with some PCs / laptops (e.g. MacBook) … OR … some students may be unaware of how to sync some devices (e.g. Blackberry) with some PCs / laptops (e.g. MacBook)

Factors are sometimes referred to as Quality Attribute Scenarios (QASs) in a general sense which will normally have related use case scenarios defined so that requirements can be linked to them and tested. When there are conflicts in factors, it is classified as an issue and where there are issues there will likely be factors to be identified and strategies to address the issues. These may be indefinite, later to be confirmed within the architectural model for the system. An example of an issue is in the following statement from another student stakeholder.

"I would use my smartphone if I was desperate as in location difficulty; internet access is limited in some places. However due to the small size of the screen I would prefer to use a tablet or a PC."

The above statement technically an issue for the goal of the system can reveal several factors:

- Internet access is limited in some places
- Small size of the screen
- There is a preference for tablet or a PC

The example has also shown how factors inherent within issues can be identified and categorised. The goals of a system can be represented by the factors. Issues can be derived goals that meet the requirement of the factors. Reference [18] refer to these as "issue-goals" and described the dynamic as that of developing a product (solution) that "satisfies a particular combination of factor-goals". Strategies can be decisions contributing the satisfaction of issue and factor goals [pp. 153]. Factors, issues and strategies need to be managed or they might grow into unmanageable levels in the global analysis [18].

C. Quality Attribute Scenarios (QASs)

QAS is another RE technique for categorising information obtained during the elicitation process. The importance of using QAS to further categorise information was mentioned briefly in previous sections. QAS is recommended in architectural requirement engineering in general for collating concerns from stakeholders and categorising them. They provide a "structured textual" way of managing stakeholder concerns and describing how it may respond to the introduction of certain stimulus. A QAS may have the following: stimulus, origin or source of the stimulus, artefact to be stimulated, stimulus context or environment, response to the stimulus and response measure i.e. satisfactory response to the stimulus as its properties [18, pp. 143].

For example, consider the following scenario in an ML system:

"In a BYOD (Bring Your Own Device) scheme in a university, a student requests support for a new type of device after staff training for known systems have been completed. An IT service support personnel was able to figure out how to resolv*e the student's problem without any* need for likely costly support required from the device manufacturer nor was there any significant delay in supporting the student. The staff documented the process and trained other staff colleagues to support similar devices within one week."

The above example can be categorised into QAS parts as follows:

Stimulus: Support request for a new type of device.

Stimulus source: A student.

Artefact: The system and the IT service department.

Environment / context: After staff training for known systems has been completed.

Response: An IT service support personnel was able to figure out how to resolve the student's problem.

Response measure: No likely costly support was required from the device manufacturer nor was there any significant delay in supporting the student. The process was also replicable as part of operational strategies in the department within one week.

Not only has a QAS been defined for this scenario, it is also possible to now derive a requirement for the system, based on the QAS process:

- zero device manufacturer support
- no extra delay
- process re-engineering within one week

The following may also be inferred through the QAS process which could form part of the requirement specification:

- Since there is no device manufacturer support, there must be a limit to the types of devices that can be supported. If there is device manufacturer support in place, potentially any type of device may be supported.
- Delay in supporting the student's device may create a negative impression about the department's effectiveness.
- Process re-engineering will require a member of staff with adequate expertise to document the process and train other colleagues to carry on the process in future.
- The staff with the expertise is already a member of the university and part of the system i.e. a stakeholder within the system.

In considering the use of QAS, [18] cautions that it is important to remember there will likely be changes to stakeholders' priorities and to ensure use case scenarios are defined in addition to QAS.

D. Use case analysis and scenarios

Use case analysis is a process modelling technique used to analyse processes so that the relationship of the process within the system to external systems or components can be evaluated and understood fully. Like a QAS, use cases have several parts as follows [18]:

- Actors / users, interacting with the use case.
- Events depicted in the system causing the use case to occur.
- Pre-conditions that must be true for the use case to occur.
- Post-conditions that must be true after the use case has completed successfully.
- Activities within the use case.
- Included use cases for other processes, if any.
- Extended use cases for processes that may take place (optionally) while the use case is occurring.

Use cases are sometimes better defined using scenarios. An activity diagram can also be used to define all possible scenarios within use cases. In a QAS, scenarios involved may include those occurring during normal operations, system-as-objects i.e. passive objects and growth – dealing with changes and exploratory, as well as those dealing with scenarios that are unlikely to occur.

E. Using goal-oriented modeling techniques

Goal-oriented modelling is a useful technique for refining the goals of the business which can be associated with the requirements and needs of a system. They are particularly useful for revealing the relationship between the business goals of the system and functional as well as non-functional requirements of the system.

Review of literature has revealed that one of the problems for the sustenance of ML is the difficulty in quantifying precise benefits when used within a learning process. Defining requirements for the system from business or strategic goals of the learning establishment could be a useful way of establishing relevance to strategic decisions and processes. Goal modelling are often used with Quality Assessment Methods (QAMs), which is a measure of how the defined goals meet the desired quality expected of the system. QAMs can be used as checklist for guiding against the omission of important non-functional requirements. The goal modelling technique presented in this paper illustrates how requirements can be inferred from business goals and strategies.

There are many approaches to goal-oriented modelling, including KAOS, mentioned earlier in this paper, and Non-Functional Requirements (NFR) framework [23] citing [24], [33]. Reference [19] stated that KAOS is "the most formal application of the goal-oriented approach to deriving requirements for computer-based systems" [pp. 15].

V. DERIVING REQUIREMENTS FOR MOBILE LEARNING (ML) FROM GOALS: A CASE STUDY

There could be a disparity in what an organisation define as business goals and what is actually offered in practice. This can sometimes be very costly, leading to losses in revenue and / or goodwill branding as well as inefficiencies. Defining and implementing Quality Attribute Requirements (QARs) may guide against this or minimise the likelihood of devastating differences. Another way may be to develop requirements from the business goals of the organisation [19]. Extracts from the policies and strategies proposed in a white paper by a UK HEI will be used in this section to illustrate this. The HEI is located in London, with campuses in the East. Relevant policies in a strategy document include the following [34]:

- We will ensure that our campuses are an identifiably academic environment with innovative provision for digital mobile learning and spaces for both collaborative and reflective study.
- We will be recognised as a leading university for employability and enterprise, routinely exceeding benchmarks and providing transformational opportunities.
- In all of these areas we will seek to be at the forefront of removing barriers to progression to further study for first-generation undergraduates, supporting access to employment and postgraduate qualifications. In this way, and others, we will facilitate greater UEL student competitiveness in employment markets and subsequently through CPD for promotion and career enrichment.
- In developing a more flexible offer for a more distributed, more mobile and more time-conscious market, we will enhance our distance learning capacity, partnerships and support mechanisms.
- We do not intend to invest significant amounts of capital in these ventures, but will explore a range of collaborative models in partnership with established and new high-quality providers.
- Over the period of this Strategy, when core, full-time undergraduate numbers are likely to remain restricted, there is a greater need than ever for us to deliver our programmes at times and in places which suit the learner. Both teaching and support need to be flexible so that students can access them appropriately.

From the list above, we can identify the following goals:

- Provision for digital mobile learning and spaces for both collaborative and reflective study.
- Provision of transformational opportunities.
- Removal of barriers to progression & facilitation of competitiveness in employment.
- Development of more flexible offer for a more distributed, mobile & and time-conscious market.
- Exploration of a range of collaborative / high-quality partnerships.
- Delivery of programmes at times and in places which suit the learner.

In deriving requirements from goals, [19] suggests a successive decomposition of the goals at the high level. The author suggests using adapted notations to decompose each goal into sub-goals where either all or at least one of the sub-goals will need to be realised for the high-level goal to be satisfied. When all sub-goals must be satisfied, this may be indicated with an arc across the directional arrows. Some goal components may also become sub-goals / requirements for the system. This resulting model is sometimes referred to as goal hierarchy or goal lattice [19]. An illustration can be seen in Fig. 1.

There are several taxonomies in use for defining QARs including ISO 9126 containing 22 quality attributes, including for example the use of ambiguous terminology in definitions [18].

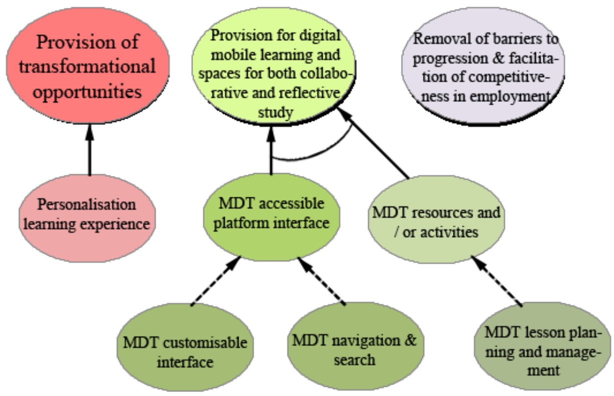

Fig. 1: Goal decomposition from business strategies

Some of the above statements / goals may fall into the category of those needing more clarity and less ambiguity which can be achieved by defining QARs. [18] suggests an integrated approach to defining QAR i.e. defining QAR from an integrated requirements model involving all the functional requirements and architecture of the organisation's operational system. For this, the authors recommend the use of an integrated artefact model (see Fig. 2) as well as goal models to show the artefacts within the system as well as the relationships linking the functional and architectural requirements.

A. Integrated artefact model for ML

Having derived requirements from the goals of the HEI (listed above) using goal-oriented modelling approach (see Fig. 1), an integrated artefact model architecture can also be created to show the relationship between the objects within the system and the attributes, as shown in Fig. 2. Defining the relationships between each of the artefacts within the system will make it possible to define QARs for the system. Relationship of the objects within the system to factors, issues, strategies and also the placement of test cases are included; as well as how QARs may be applied to use cases, scenarios and functional requirements. An integrated artefact model architecture will also allow for "trace relationships" which are sometimes overlooked to be clearly defined and established (4).

Artefact models are particularly useful for aligning project goals within the broader goal(s) of an organisation. Symbolic notations are often used in some artefact modelling to illustrate relationships between the objects. Some may be defined using predicate logic language involving the use of symbols, quantifiers and logical operators. For example, the predicate equal(A, B) indicate A = B; plus(A, B) indicate A should be added to B and so on [35]. Using techniques such as predicate logic language notation for artefact modelling can however render the model too complex for those without expert knowledge on the subject [16].

Integrated artefact modelling can be simplified by using standardised object relationship notations commonly used in computer system modelling to reveal how the components of a system may be dependent on each other, guiding requirement specification for the system [18]. To illustrate, an integrated artefact model architecture showing how components within the problem statement for mobile learning is shown in Fig. 2. The model shows when QAWs, QASs and test cases may be required for the system. It also reveals when QAR may be needed to guide against extreme differences in opinion among stakeholders. Use cases will need to be established for testing how well the requirements achieve defined goals as well as the functional / non-functional specifications.

VI. Conclusion

In this paper, the use of RE is proposed to explore relationships between MDT and education. Work presented in this paper is part of an ongoing study involving the application of RE techniques in an HE setting, and this work is yet to be completed. Therefore, a full picture of the requirements and goals for the system are yet to be established. The paper has however shown how RE techniques can be of some considerable benefits when used in systems such as ML, in spite of the very challenging prospect of usage within the complex contexts characteristic of ML systems.

A peripheral question in the wider context not addressed in this paper is how a co-evolution relationship between MDT and education may impact these requirements and goals. Arguably, early promises of a technology are often overshadowed by the "hype" accompanying technological adoption in learning establishments. Some technological systems are eventually found to be either badly managed, unfit for purpose and / or mal-aligned with the broader learning and teaching strategies of the organisation; as noted by Gartner, describing this phenomenon as typical Hype Cycle behaviour. Hype Cycle is the graphical representation of the phases of technological adoption and integration into the marketplace. Early adoption often follows rapidly after a trigger period and Research & Development (R&D. This phase is characterised by scores "inflated expectations" and sometimes ill-judged experimentations. The process continues through periods of disillusionment, enlightenment and productivity in a graphical maturity curve. A likely phase at any time could of course be obsolescence, if the technological system implementation is impracticable or unfit for purpose [36].

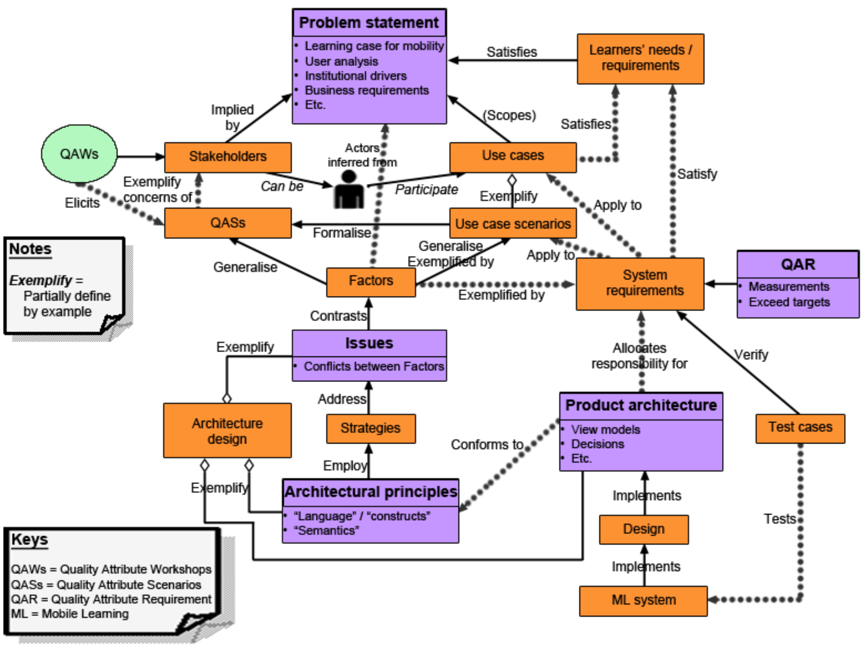

Fig. 2: Integrated artefacts model architecture for Mobile Learning (ML)

Modified from source [18, pp. 130]

Apart from educating a subset of its citizens, two other important functions of HEIs within a nation are "research and innovation", as noted by Professor Paul O'Prey (Vice-Chancellor, University of Roehampton and Chair, Universities UK Longer Term Strategy Network), writing a preface for the 2011/12 UK Higher Education Statistics Agency (HESA) report [37, pp. 2]. It may be a generalised view to state some have found injecting innovation into HE practices including those relating to technological adoption almost impossible. Regardless, and to move the agenda for ML forward, a likely area of further study may be to what extent (if any) HEIs are able to influence products emerging from the R&D phase of technological development and manufacture. Are there any attempts to determine the needs and requirements for learning and advancements and to what extent are these driving the direction and marketisation of advancements? Also related to this track is how quickly and effectively members of educational community innovate and review its learning and teaching strategies / practices to ensure educational technologies such as MDTs are fully integrated; progressing seamless and rapidly towards the productivity phase of the Hype Cycle soon after adoption. Ensuring this occurs will not only save time and effort, but prevent wastage, redundancies and / or inertia that is fast becoming commonplace in many technological adoptions, including MDTs, in learning and teaching.

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