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# Application of Requirement Engineering and Agent Oriented Software Engineering Modelling techniques for Mobile Device Technologies Integration in Learning Establishments

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**ABSTRACT**
Mobile devices have been around for over a decade. Yet, their expected potential to effect learning transformation is largely unfulfilled. Evaluating and quantifying benefits, either through achievement of learning objectives or enhancement of the process remains problematic as rapid changes in development and manufacture continue to present additional challenges. Most trials typically employ use case approach, evidencing benefits through experience. In this paper, application of Computing / Software Engineering disciplines such as Requirement Engineering (RE) and Agent Oriented Software Engineering (AOSE) are proposed. RE techniques have proven useful for analysing systems to aid goals and requirements specification. Used in conjunction with methodologies designed for AOSE and agent-based systems with complex human interactions, goals and specifications can be more easily aligned with a learning establishment's overarching mission / goals. The use of these techniques for Mobile Learning (ML) will be illustrated in this paper with a case study in a bottom-up approach. Alignment with teaching and learning strategies as well as institutional goals, policies and strategies are considered essential for successful integration of Mobile Device Technologies (MDTs) in learning and effective ML implementations. This paper will present example goal models for sustainable ML in learning establishments.

**KEYWORDS**
Requirement Engineering — Goal-Oriented Requirement Engineering — Agent Oriented Software Engineering — Tropos Methodology — Goal Modelling — Mobile Learning — Mobile Device Technologies.


## 1. Introduction

Educational communities have honed the art of appropriating innovative technologies to enhance learning and transform the system [1]. This practice have been described under several terms, leading to the development of "educational technology" as a discipline; 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 [2]. However, in spite of these efforts with often mixed results, the community remain on the left foot forward; playing catch-up as advances in technology continue to break moulds; previously innovative ideas becoming 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 operations; individuals, groups and communities use them to augment life styles choices and coordinate relationships; government, news media outlets, security experts and organisations depend on them to support information frameworks on the one hand while justifying intrusions into people's privacy on the other. The society as we know it in this generation is rapidly changing as a result [3]-[4].

In contrast, current students in UK educational sector 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. Many educators confess they have no clue about precise benefits to learning or how this may be applicable to their teaching practice. 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 and refusing or unable to explore whatever opportunities they may offer for learning transformation [5].

Using Gartner's hype cycle methodology, [6] charted ML's progress from findings of Universities and Colleges Information Systems Association (UCISA)'s longitudinal study (2001, 2003, 2005, 2008, 2010 and 2012) on Technology Enhanced Learning (TEL) in UK Higher Education (HE). The hype cycle placed ML (Mobile Learning) in the "trough of disillusionment", suggesting interest is not as keen as it may have once been within the domain (Figure 2).

Arguably, early promises of innovative technologies are often overshadowed by the "hype" accompanying their adoption in most cases; but perhaps particularly true in learning establishments (Figure 1). Some systems are eventually either badly managed, unfit for purpose, inadequately funded and / or supported, and / or mal-aligned with the broader learning and teaching strategies of the organisation, as noted by [7]. Regardless, 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 [8]-[10].

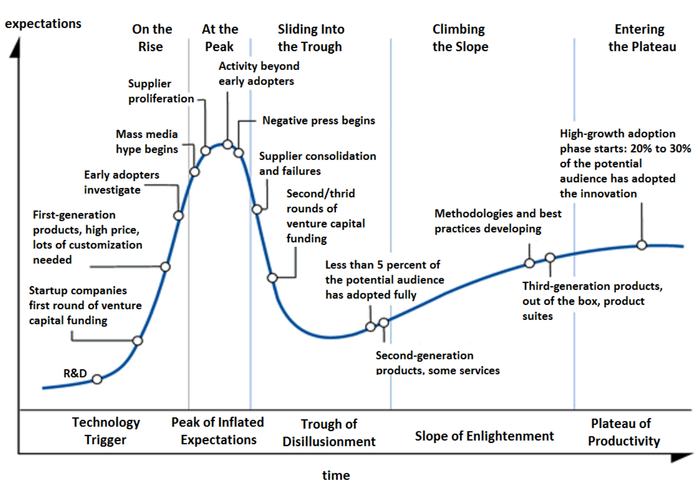



**Figure 1.** *Hype cycle of technology's lifecycle ([7]; cited in [15]).*

This may be influenced in part by Government and think tanks' conviction these technologies and information mobility within the society are crucial for future developments [11]. It is no secret the UK government make considerable efforts to facilitate mobile device usage in the constantly evolving provision of robust internet and WiFi connectivity. It has been a core part of policy strategies of incumbent UK governments in recent past [12]. 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" [13]. And yet, some of the staff respondents in schools, FE colleges and HE admit they either have zero or very little support to connect or are unsure of how to use them in teaching and learning practices still, in response to a mobile learning study conducted recently [14].

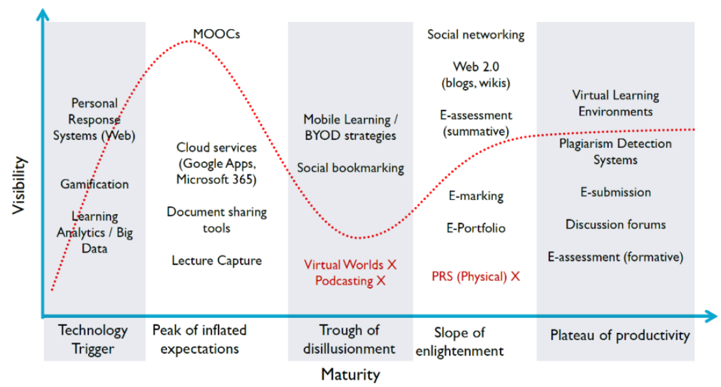



**Figure 2.** *TEL hype cycle showing placement of activities in ML (Based on [7]'s hype cycle methodology; cited in [6]).*

In some respects, BYOD schemes are sometimes little more than strategic ploys to minimise infrastructure costs while ensuring competitiveness (or the appearance of it) in provisions without really addressing any of the underlying issues or potential benefits. Equally, many support staff respondent to a recent study admit they are struggling to meet the demands for expertise on some of the less common or recently released devices [14]. Many also feel inadequately equipped or supported by their 'home' organisations; with no training provisions and / or expert support knowledgebase [1], [16], [17, pp. 24].

Accordingly, the almost 'lightning-speed' pace of advances in MDTs continue to present 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 ML is here to stay just as MDTs are seen as a core part of future educational transformation [14]. Others would add, perhaps cynically, there is no evidence of actual learning involved in some efforts, the devices used primarily for access and delivery only for the most part [18]-[19].

Given these phenomenon and increasing changes in communications / consumer behaviour and social interactions resulting from MDT integration in other sectors within the society, expecting a similar trend in education is perhaps understandable. However, by all accounts, the educational community seem unable to see those benefits or unsure how to integrate MDTs into their practice [20]-[24]. Nonetheless, the perceived inertia or decline in interests (Figure 1) may offer support for the need for a different approach [23].

In this paper, a look to abstraction and system modelling methodologies in Computing / Software Engineering disciplines are proposed in the application of domain neutral Requirement

Engineering (RE) and Agent Oriented Software Engineering (AOSE) methodologies to explore "real world" systems such as Mobile Learning (ML). It is anticipated this will provide more insights into the underlying issues in the domain, and aid alignment with business goals and policies for sustainability. The application of these techniques to explore the relationship between MDTs and education is presented in this paper, along with a case study and illustrations outlining the approaches proposed.

## 2. What is Requirement Engineering?

Reference [25, 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 [26, pp. 3] added 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 [26] outlined its suitability for specifying what the authors called "real-world goals" i.e. reflecting the tendency for change in the real world. More recently, [27, pp. 42] agrees, adding "each RE process starts with an aim to change the current reality". The author stated all software systems are used within a context, adding while system goals may be clearly defined, quite often variables within the context are not so clear. The latter may be more useful in establishing a rationale for the application RE methodologies for ML systems. Although not strictly a software-intensive application 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, not only enabling easy collaborations between geographically dispersed individuals, but also creating convergences between multiple media devices. Crucially, they also provide 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.

## 3. Application of Requirement Engineering techniques in Systems

According to [28], there is no one prescriptive way of applying RE techniques to analyse a system but the authors caution on ensuring techniques are applied early in the system lifecycle. With so many to choose from, selection of 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 [29].

Regardless, many authors agree the following core stages are essential in RE [28], [30]-[31]:

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

The distinction between some of these stages may be blurred to some extent, requiring some steps are carried through the life of the project / analysis. Some of the activities involved in each of these stages will be discussed next.

### 3.1 Elicitation of Needs

The bulk of the fact finding process in RE is usually in the inception and elicitation phase. However, elicitation is a task that will continue throughout the life of the project and beyond implementation. For example, whenever changes are made to a system, requirements for those changes have to be re-evaluated [31]-[32]. Reference [31] cautioned that not all the information obtained would become requirements. Some needs may not be feasible to implement in the final product.

Elicitation is conducted among all stakeholders within the system and there are several 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 [33].

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. Moreover, 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 [18].

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 [34]. 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"; indicating some extreme opinions may be held by some stakeholders still [14].

It is also important to identify sub-groups within each stakeholder groups with potentially differing opinions. For example, educators' group may include tutors and pre-service tutors who may also be students themselves in HE; with perhaps conflicting usage requirements and perceptions. Reference [35] 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 [31] 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) [10], [31], [36] citing [37]. KAOS specify the use of verbs as well as AND / OR operators to link goals to processes [38]. Goal modelling will be discussed and illustrated in more details later.

Other elicitation techniques include ethnographical research methods [28]. 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 [31]. Brainstorming and prototyping may also be employed during the elicitation stage.

### 3.2 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 [30].

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 [39] suggest the use of trade-offs adding 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 the table depicted in Figure 3. The table shows strengths in opinions and level of importance by doubling or tripling certain symbols.

Reference [31] 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 using "structural natural language description" [pp. 131]. Each concern is illustrated with a relevant example and each stakeholder may 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. The use of QAS in RE will be explored in more depth later.

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 [31]. 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 [40]-[41].

### 3.3 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 [31]:

- **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.

| Goals | Functional requirements / stakeholders | | | | | | Non-functional requirements (NFRs)* | | |
|---|---|---|---|---|---|---|---|---|---|
| | 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.*
*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

**Figure 3.** *A sub-set of trade-off analysis table for a Mobile Learning (ML) system.*

In subsequent sections of this paper, techniques applicable to the ML system are illustrated in more details.

### 3.4 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 [26, 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. A case study using goal modelling to specify goals for an ML system will be used to illustrate these techniques later. 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.

## 4. Establishing and Classifying 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 [38], [42]. Both of these authors believe while many appreciate its importance, processes involved in specifying the goals of a system are often side-lined in literature and formal specifications. 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 [38] refer to this as the "top-down" approach [pp. 3].

For [31] and [38], 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 [38] 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 [31], [38].

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.

### 4.1 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 goals are sometimes also referred to as functional specifications for the system. For example, in 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 [43]-[44]. 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 utilised in testing the system from developed use case scenarios; which can be generated from the factors [45].

### 4.2 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 [43]. Reference [38] 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 may recount: "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 can be identified in the following statement from a 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 [31] 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].

It should be noted factors, issues and strategies need to be regularly reviewed and managed or they might grow into unmanageable levels and rendered unusable in Global Analysis [31].

### 4.3 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; especially as a tool in QAWs. 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. Thus, a QAS may have the following components: *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 [31, 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 resolve 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.

Consequently, not only can a QAS be defined for the scenario, it is also possible to derive requirements 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, [31] cautions 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.

### 4.4 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 [31, pp. 59].

- **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.

### 4.5 Using Goal-Oriented Modelling 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

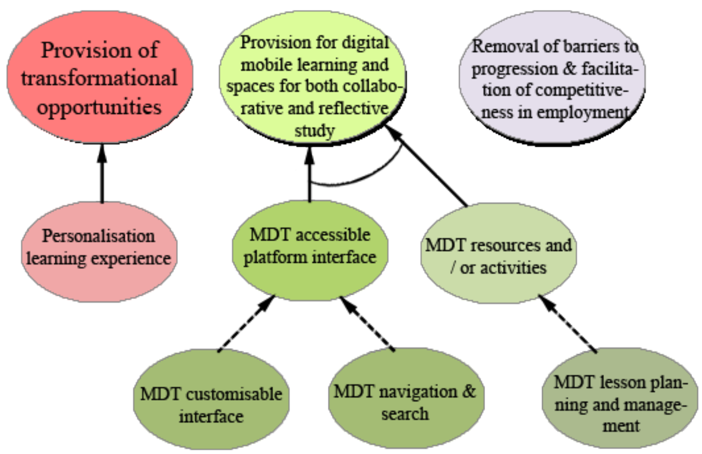



Figure 4. Goal decomposition from business strategies.

**Figure 4.** *Goal decomposition from business strategies.*

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 [36] citing [37], [46]. Reference [32] stated that KAOS is "the most formal application of the goal-oriented approach to deriving requirements for computer-based systems" [pp. 15]. The use of factors, issues and strategies have also been illustrated in previous section. The goal of the system can be represented by the factors; issues are derived goals that meet the requirement of factors.

## 5. 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 [32].

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 [47]:

- 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. In particular, we will seek to double our recruitment of new distance learning students by the end of the decade and establish a clear position as the leading distance learning provider in the UK after the Open University.
- 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, [32] 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 [32]. An illustration can be seen in Figure 4.

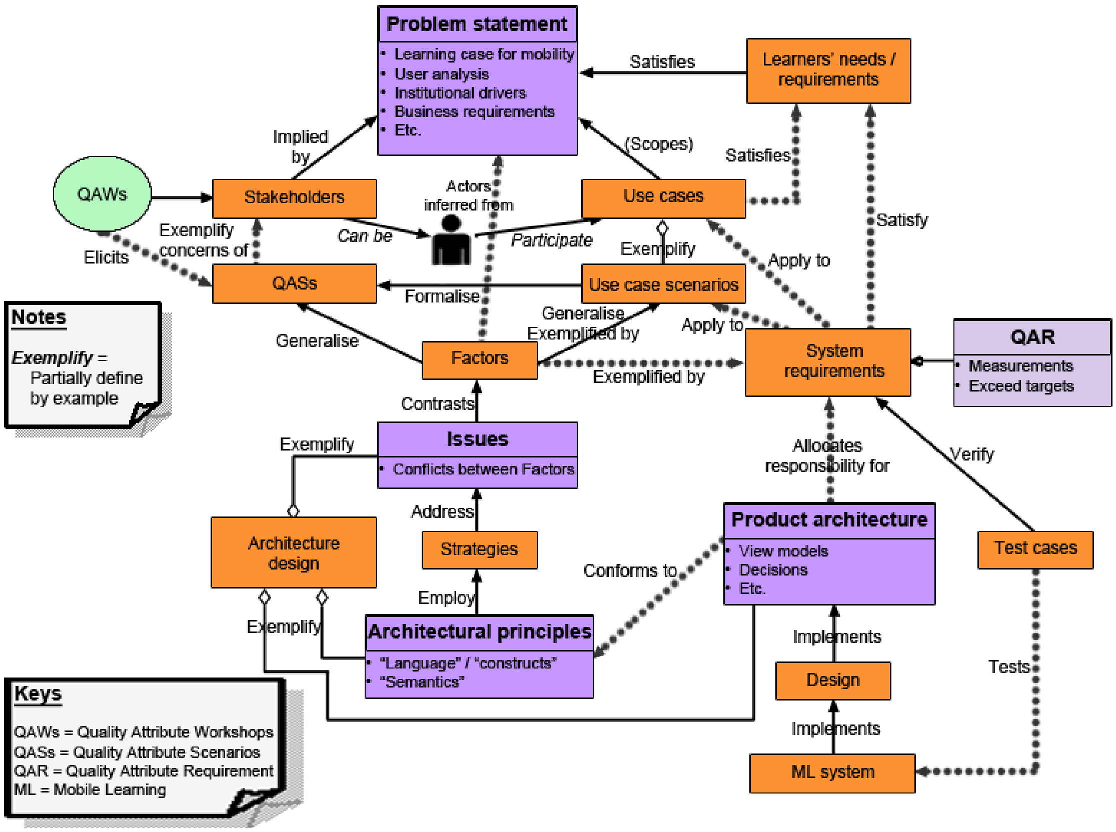



**Figure 5.** *Integrated artefacts model architecture for Mobile Learning (ML).*

There are several taxonomies in use for defining QARs including ISO 9126 containing 22 quality attributes, suggesting for example the use of unambiguous terminology in definitions [31]. Some of the statements / goals extracted from an HEI white paper earlier may fall into the category of those needing more clarity and less ambiguity which can be achieved by defining QARs. [31] suggest 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 (Figure 5) as well as goal models to show the artefacts within the system as well as the relationships linking the functional and architectural requirements.

### 5.1 Integrated Artefact Model for ML

Having derived requirements from the strategic policies of a UK HEI in the previous section using goal-oriented modelling approach, 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 Figure 5. 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 use case scenarios which can be defined for the factors.

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 [48]. 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 [29]. Therefore, relatively simpler notations, such as those specified in the *i∗* framework for use in Agent Oriented Software Engineering (AOSE) discipline by [49] may be employed.

Integrated artefact modelling can also 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 [31]. To illustrate, an integrated artefact model architecture showing how components within the problem statement for ML is shown in Figure 5. 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.

Textual descriptors have been added to describe the relationships between the components of the model in Figure 5 for clarity. Used alongside a full goal model specification (Figure 4 for an example) and other relevant system requirements, it should now be possible to elaborate on goals for the system, aligning these with strategic goals for the organisation. Requirements for achieving the latter can also be specified and use cases defined for testing how well requirements may achieve the strategic goals.

# 6. Overcoming Limitations of RE Goal Models

In system modelling, establishing roles and allocating responsibilities are arguably two of the key tasks in systems requirement specification. However, according to [50], these tasks are sometimes overlooked or given less attention than they deserve in modelling / specification documentations. Illustrating the problem with a 3-tiered pyramid locating 'tools' at its apex, 'people' at the base and 'processes' in the middle, [50] argue human factor in software development often fail to get enough attention; advocating turning the pyramid on its head and putting people first.

While the ability to explore a system from stakeholder perspective and establish a set of requirements that has taken the human factor into consideration is a core strength in RE, resulting models and requirements from RE techniques can sometimes become too complex and detailed to be usable by any but knowledgeable experts [29]. Consequently, methodologies and notations commonly used in other disciplines such as AOSE may be employed in conjunction with RE and goal modelling techniques to derive usable models for resolving system problems.

## 6.1 Agent Oriented Software Engineering (AOSE)

The discipline of AOSE gained some grounds over the last decade, not only "as a design modelling tool" but also "as an interface to platforms which include specialised infrastructure support" as well as complex "interacting processes". It is particularly useful for the exploration of "software agents and multi-agent systems" [51].

An agent can be described as an entity capable of running routine tasks to achieve specific goals within a system [52]. While such agents are typically computer programs performing functions within a software application or programming environment, system modellers may also depict human interactions as agents or actors within a system. In this sense, an ML system may qualify as an agent-based one; benefitting from the application of common methodologies in AOSE discipline such as Tropos, MESSAGE, MaSE, Prometheus and Gaia.

Tropos methodology has been selected for illustration in this paper because of its foundation on Eric Yu's $i*$ modelling notations with relatively easy-to-understand specifications for actors, goals and dependencies. These are considered to be particularly relevant in creating easily understood models reflecting roles and relationships within a system.

## 6.2 Tropos methodology

Tropos methodology outline techniques in phased stages which include early and late requirements specification for a system. This is essential for ML systems because as well as providing means by which elicited goals, activities and requirements of a system may be classified, it also allows for further incremental refinement and identification of the relevant components. In addition, modelling may be constructed in the context of the organisation within which the system operates [53].

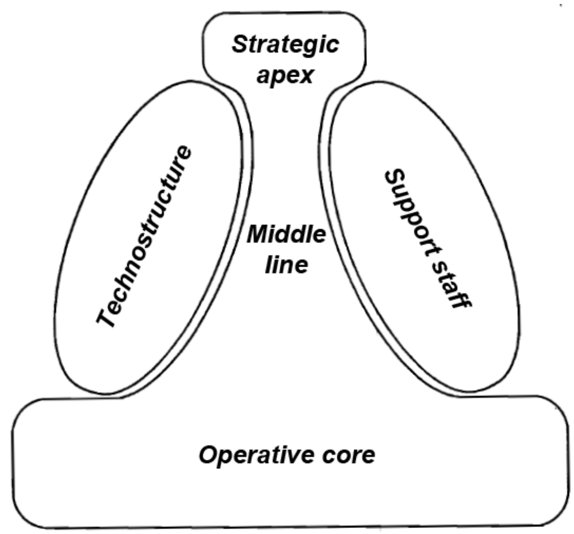



**Figure 6.** *Mintzberg's Structure-in-5 organisational model ([54, pp. 33]).*

Therefore, the resulting models captures WHAT the system does and is all about, HOW these activities as well as responsibilities are performed or executed and WHY a particular analysis, artefact or the system itself may be necessary or implemented [38, pp. 3]. Finally, the simplicity of the common terms and logical notations employed in Tropos methodology allow for greater clarity and ease-of-use, while also providing traceability through multiple phases i.e. allowing for "artifacts" or requirements defined later to refer "back to artifacts or requirements" produced during previous stages [55, pp. 3].

## 6.3 The $i*$ framework notations

Table 1 describes the $i*$ framework syntax notations. Actors carry out actions that will achieve a specified goal. An actor may be a single individual or a unit or department with specific functions or activities e.g. a person in 'academic tutor' role or student enrolment department. Agents are actors physically manifested within a system; human or artificial intelligent i.e. programmed agent.

Association links show dependencies and relationships between actors. A *depender* is an actor who depends on another actor in a relationship. *Dependee* is the actor who is depended upon while *dependum* is the agreement or element between actors which can be either goals, *softgoals*, *tasks* or *resources*. The relationship is represented in the form: *depender* $\rightarrow$ *dependum* $\rightarrow$ *dependee*.

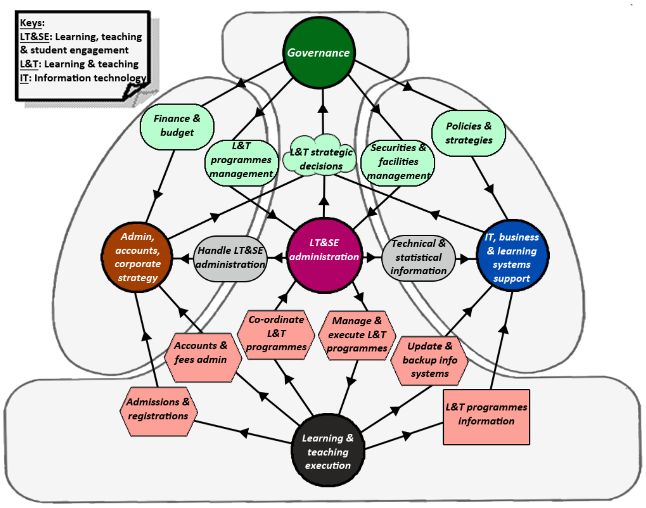



**Figure 7.** *Structure-in-5 model for HEI, based on [54]'s Structure-in-5 model.*

Goals are *functional requirements* with responsibilities for actor depender and dependee. Soft goal (softgoal) are *non-functional requirements* or goals that may be subjective or incapable of being satisfied precisely. Tasks represent an activity to be performed by the dependee and resource is provided by a dependee to the depender.

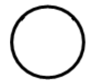
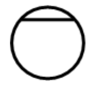
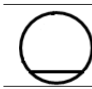
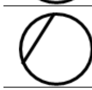
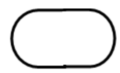
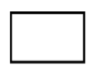
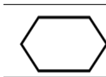
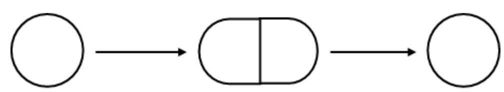
### 6.4 Aligning goals for ML with strategic policies

As mentioned before, Tropos methodology allows for systems to be specified within organisational contexts. Reference [56] would suggest [54]'s structure-in-5 organisational model (Figure 6 & 7), based on the understanding a system does not exist in a vacuum and are operated within an organisation. Defining a system in organisational context makes it possible to reflect the actor / agent positions within the system as well as roles, positions and the tasks they perform. It also makes it easier to align the strategic goals of the organisation with actors, agents, roles, positions and tasks; reflecting the dependency.

Applying the structure-in-5 organisational model in HEI context may produce the model depicted for illustration purposes in Figure 7. The figure outlines likely units and sub-units in an HEI. It is important to note units / sub-units represented in Figure 7 may be reflected differently in HEIs and the model should be adapted accordingly.

In Figures 6 & 7, the *i*∗ notations for specifying *depender* $\rightarrow$ *dependum* $\rightarrow$ *dependee* can be used to link goals, tasks, softgoals and the relationship existing between the positions. For example, the strategic apex is the *depender* for technostructure, middle line and support; all three are *dependees* to strategic apex, and the *dependum* should be goals for the organisation or section or group. Technostructure, middle line and support have a softgoal dependency while technostructure, middle line and support have goal (hardgoal) dependencies between them [56]. Middle line and operative core can only have task dependencies between them with middle line as *depender* or *dependee* and operative core as *dependee* or *depender* as the case may be.

**Table 1.** *The i* framework syntax notations.*

| Notations | Description |
|---|---|
|  | **Actor**: Carries out actions to achieve a goal. May be a single individual or a unit which carries out specific actions to realise specified goal. |
|  | **Agent**: *Actors* that are physically manifested e.g. human or an artificial intelligent agent. *Agents* play roles and occupy positions. |
|  | **Role**: played by *agents*. |
|  | **Position**: cover *roles*. |
|  | **Hardgoal**: Specific goals / functional specifications for the system e.g. *'passing the assessment examination'*. |
|  | Softgoal: Non-functional specification; a measure of how well functions within the system have been achieved; but they may be subjective and non-achievable e.g. *'passing the assessment examination with distinction'*. |
|  | **Resource**: provided by actors in a dependency relationship. |
|  | **Task**: represents activities performed by a *dependee*. |
| **Dependencies** | |
|  *Depender* $\Rightarrow$ *dependum* $\Rightarrow$ *dependee* | |
| | A dependency describes an "agreement" (called *dependum*) between two actors: the depender and the dependee. The *depender* is the depending actor, and the *dependee*, the actor who is depended upon. The type of the dependency describes the nature of the agreement. |

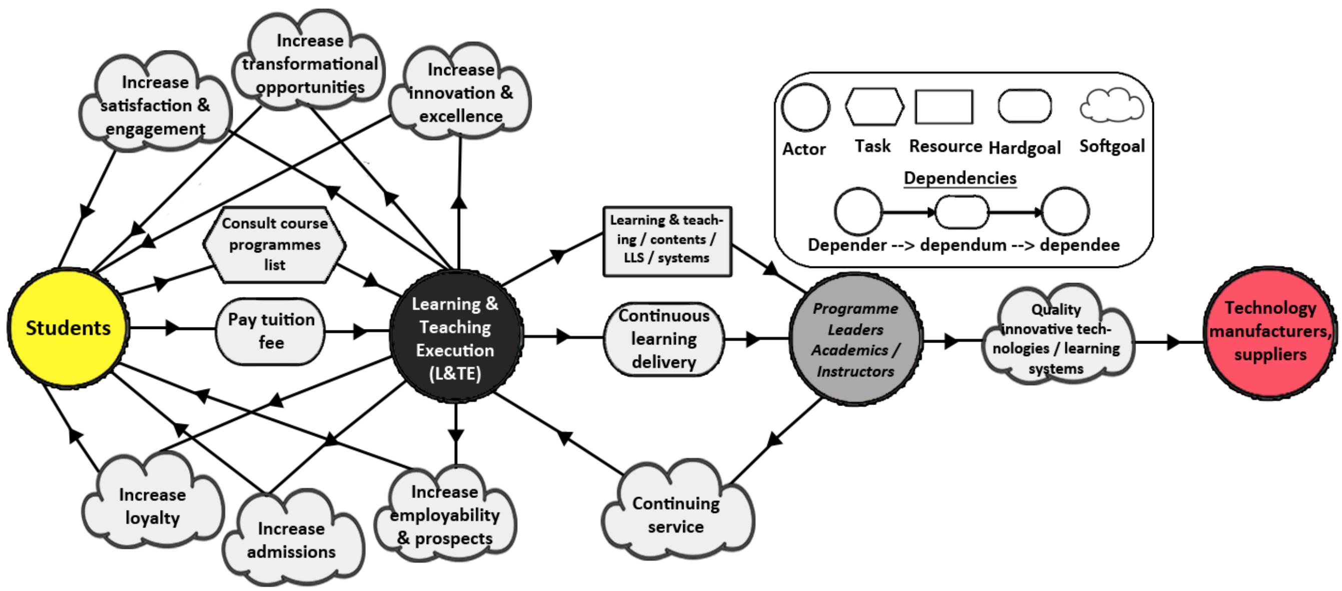



**Figure 8.** *Strategic dependency model for the operative core (Learning and Teaching Execution – LT&E) in HEI.*

Figure 8 goes a step further to present a strategic dependency model derived using goals derived from extrapolated policies for learning and teaching, extracted from the white paper of a UK HEI. The dependency model illustrates overaching dependencies that may exist between learning establishments and external partners. It is based on a model developed by [53, pp. 4] for a media shop, aligned with Mintzberg's Structure-in-5 organisational model. The "*strategic dependencies*" may be assumed to represent those present within the *operative core* of Learning and Teaching Execution – LT&E in an HEI (Figure 7).

Other HEIs may have different strategic policies, with variations of some of these objectives expressed in one form or the other. For example, some of the listed objectives were also identifiable from the teaching and learning or e-learning strategies of [57]-[59]. Invariably, these may form part of the requirements, quality dimensions and goals for the organisation.

## 7. Conclusion

In this paper, a discourse on the application of techniques and methodologies in RE discipline that may be used to explore systems such as ML and the integration of MDTs in education are presented; a case study based on extracts from the policies and strategies proposed in a white paper by a UK HEI used as illustration. The resulting models suggest how explorations within the domain of ML as well as the relationships between MDT and education may be modelled to highlight issues and shortcomings within the system.

Finally, the paper highlighted some of the shortcomings of RE, illustrating how these may be overcome in the application of Tropos methodology employed in AOSE disciplines, using the $i*$ framework syntax notations. This allows for relatively easy-to-understand models of the system to be created within organisational settings. Modelling the system from organisational viewpoint is expected to aid alignment with institutional strategies and policies; suggested crucial to successful integration and sustainability in this paper.

An area not addressed in this paper is how perceptions, organisational culture and practices may influence requirement specification processes. For example (as in this particular case), the traditional relationship between students, learning establishments and other stakeholders within it can be complex but commonly represented or 'seen' in a hierarchical 'student to educator', 'novice to expert', 'apprentice to mentor' etc., relationships. Thus, the seat of power and the dynamics has always been well understood, leaving students sometimes powerless to effect desired changes or obtain satisfaction. Potentially, there may be factors and issues to be addressed within these relationships as well as their impact on strategies and change management efforts.

Another problem not addressed is the question of what form learning transformation should take; which may not only be different from one institution to another, but also diverse and / or conflicting for stakeholder groups within a given institution. Technology-enhanced learning (TEL) or blended learning are two of the more recent phrases brandied about in educational circles but there would likely be more. Should learning be left as-is or made more flexible, blended, virtual etc., or is a flipped classroom needed? Opinions are bound to vary on these issues. What's more, readily available technologies and rapid ongoing advances in developments of MDTs make them rich for speculation and appropriation.

To move the agenda for a sustained mobile learning in HE forward therefore, a likely area of further study may be a thorough investigation of the subject domain of ML and MDT integration in learning. To what extent (if any) are HEIs able to influence appropriate / integrate MDTs in a sustainable manner? How quickly, regularly and effectively are members of educational community innovating and reviewing its learning and teaching strategies / practices with full consideration for advances in educational technologies such as MDTs? How might early adopters be progressed seamlessly and rapidly towards the productivity phase of the Hype Cycle soon after adoption, allowing for timely dependency on innovative technologies?

These are a few of the likely questions for further enquiries within the domain(s) which may reveal the complexity of the situation. This paper propose a directional change in the research study approaches, suggesting computing techniques for requirements specification and goal modelling may provide better insight into the issues and problems; leading to possible solutions and a progressive way forward for ML and MDT integrations in learning.

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