KNOWLEDGE STRUCTURE MAPPING DESIGN BY EVOLUTION

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ABSTRACT

Knowledge Structure Mapping (KSM) is a method to help those responsible for any activity to more effectively manage the knowledge which is held and applied by the people.

Early experimental knowledge study systems lead to the foundations of Structural Knowledge Auditing (SKA) and a pilot project was undertaken at BA Systems in Samlesbury in 1999. Several more trials were carried out between 2000 and 2005.

In 2005 AKRI Limited began to develop KSM and produced new software with a business delivery focus. Work at Airbus UK and several projects at Rolls-Royce plc lead to a great many more refinements. Later work with the Nuclear Industry has contributed further to the evolution of the method.

Ultimately KSM has evolved through exposure to customer driven needs. The lines between research, design, development and deployment have not been drawn for this project and all four functions continue to take place.

Keywords: Knowledge Mapping, Knowledge Management, Evolutionary Design, Customer Driven.

1 INTRODUCTION

In many areas of science, engineering and even management, it is possible to make useful developments by carrying out research to uncover problems and formulate methods for the solution of those problems. Using the research results, detailed designs can lead to the development of actual systems which solve the perceived problems. Deployment can often result in some modification to the original design and ultimately to the system deployed.

In the area of Knowledge Management, tangible definitions of requirements and uncomplicated definition of problems can be rather hard to come by. Knowledge has a clear, if not controversial, definition which does not really suit the needs of business. The term management covers such a broad range of activities that it is difficult to identify good practice which applies to all aspects of management. The creation of a discipline which combines these two terms was always going to create problems of definition and resulting problems of creating good practice.

If approaches to Knowledge Management used in a variety of organisations are considered, it becomes clear that the term 'knowledge' and the term 'management' have necessarily become diluted in order to satisfy the classification of many methods as methods for knowledge management. In some cases a functional and well managed corporate Intranet provides the bulk of what an organisation might want from knowledge management. Integrated Management Systems, Document Management Systems and

other computer based systems are seen to be at the heart of knowledge management. Other tools (or rather methods) can provide options to address certain perceived needs. Amongst these are:

- After Action Reviews, to learn lessons from cases
- Communities of Practice, to encourage knowledge sharing
- Exit Interviews, to ensure valuable knowledge is not lost
- Identifying and Recording Good Practice, to help all people to always work optimally
- Knowledge Audit, to identify gaps, flows etc
- Knowledge Mapping, to map sources to needs
- Knowledge Capture, to change so called Tacit knowledge to Explicit knowledge and document it
- Knowledge Indexing, to create a directory of experts and expertise
- Social Network Analysis, to uncover how information flows through an organisation
- Storytelling, to spread good practice
- etc.

Each of these methods and many others, can solve specific problems for organisations and each is in some way associated with knowledge and is probably encouraged by management. However, non of them are explicitly helping managers to manage what people know, that is, what people have in their heads. This does not mean that they are not knowledge management or that they are not useful, just that they do not address a tight definition of knowledge management (which although not defined here either, is strongly implied by the first sentence of the abstract of this paper).

Considering definitions from this source:

http://www.knowledge-management-online.com/Definition-of-Knowledge-Management.html

identifies the lack of a well and tightly targeted understanding of what knowledge management actually is.

One very clear ambiguity is that most organisations feel that documenting their knowledge resource is a key activity in knowledge management. Yet even a simple acknowledgement that knowledge is knowing something, highlights the difficulty with this, documents don't know anything.

The pursuit of why knowledge management is not a well defined term is of no particular use to organisations because it doesn't really deliver anything. It is perhaps better, even at an academic level, to accept that whilst knowledge is a defined philosophical concept, knowledge management is a sort of catch all term which is used to provide a classification index for rather a lot of different activities.

Yet within the variety of possibilities for knowledge management, it is still possible to consider both knowledge and management as terms which combine to form a tighter option for knowledge management. Knowledge can be considered as the things that people know (because things are not known by computers, documents, books etc). Management of this resource can be considered as understanding what people know with particular respect to the things which need to be known in order to carry out some activity effectively. This approach to knowledge management can therefore provide something to draw tighter boundaries around and yet still acknowledge that knowledge management as a concept, also includes many other things.

The basic idea of this sort of definition of knowledge management is what started the evolutionary development of trial systems, of Structural Knowledge Auditing (SKA) and of Knowledge Structure Mapping (KSM).

2 THE EVOLUTIONARY PATH

A working group (The North West Artificial Intelligence Applications Group, NWAIAG) which looked at the application of Artificial Intelligence in industry, was formed in the winter of 1987. This group was based at Blackburn College, it was supported by several regional universities and it was run by an industrial steering committee. Initially, the steering committee was comprised of 9 people; these people were from Terminal Display Systems, Philips Components, British Aerospace, Royal Ordnance, Crown

Paints, Shorrock and Blackburn College. The membership of the group grew from 28 in 1988 to 84 in 1996 when Colin Cadas from Rolls-Royce took over as the chair of the group. In the early years it was Expert Systems which featured as the main knowledge based business service which the group promoted. However, early seminars on 'Knowledge Engineering', 'Knowledge Elicitation' and 'Knowledge Analysis' began to shift the focus towards Knowledge Management. By 1995, the group was offering support to business and industry in 'Managing Knowledge at Work' and had started its own research activities in Knowledge Management. On the 20th February 1996, the group held a Knowledge Management seminar at BA systems in Samlesbury which was attended by 13 people from the business and industrial members of the group. From 1996, under the chairmanship of Colin Cadas, the group gradually conducted more research in the area of Knowledge Management and on the 18th August 2000, the NWAIAG became the Applied Knowledge Research Institute. This group worked with a Knowledge Management focus until 2005 when it was permanently closed by the college. All systems produced by the group were released at that stage since all had been designed and developed in collaboration.

3 DEVELOPING THE IDEAS

Following the earliest discussions and seminars carried out by the NWAIAG it became clear that the special circumstances of the group meant that it was well placed to look carefully at how managers could use information about what their staff needed to know in order to create business advantage. By 1994, the NWAIAG had created an experimental Knowledge Management tool which was used to elicit the opinion of managers and then embed their ideas into a working pilot system. This system was not given a name at the time and has subsequently been referred to as KM1.

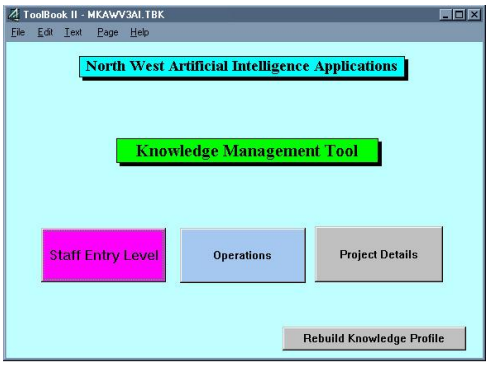

Figure 1: The front screen from KM1

KM1 was written in a multimedia package called Multimedia Toolbook. This was chosen because the initial emphasis was on the visualisation of knowledge management ideas and not on operational efficiency. KM1 looked at KM as a knowledge supply and demand system where people were the supply and projects were the demand. Sitting in the middle was an option to conduct analysis which was intended to make the supply to demand needs more visible and therefore more manageable.

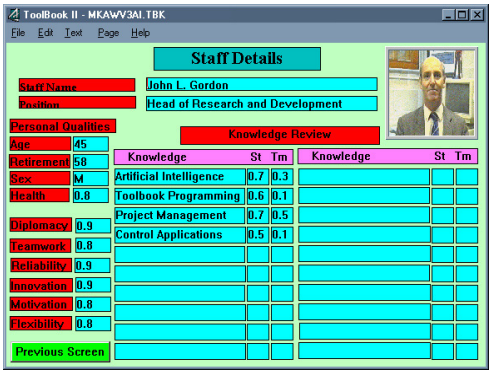

Figure 2: A Staff screen from KM1

Typically individuals were assigned values for typical qualities but the main area was the individuals expertise. This was assessed in how strong the knowledge of the individual was and how much current working time was spent using their expertise for projects. Projects were given similar demand based requirements for knowledge and the software tool was able to conduct various analytical operations which informed the managers of the projects.

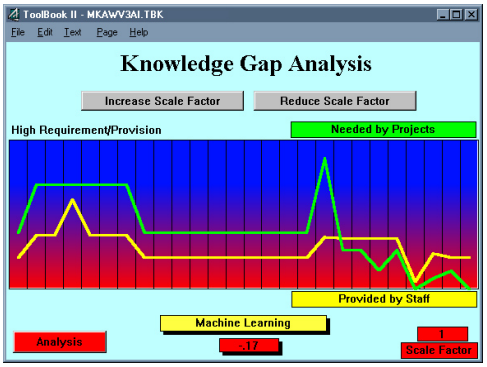

Figure 3: A Sample analysis screen from KM1

Knowledge gap was felt, at the time, to be an important thing to know about the knowledge resource and the demand for that knowledge.

KM1 was much more detailed than can be conveyed by three screen shots and was more fully described in an internal AKRI paper in May 2003. Some of the details concerning how risk was computed etc were addressed in a paper given at ES97 in Cambridge England in December 1997 (Gordon 1997). In 2003, during the AKRI lead review of this earlier work, the ideas were revisited in a paper entitled 'Risk, Gap, and Strength: Key Concepts in Knowledge Management' (McBriar 2003).

KM1 lead to ideas concerning a more targeted system which directly addressed the knowledge which people brought to bear on business and industrial problems. This was the forerunner of SKA and KSM.

3.1 A Pilot for SKA

Towards the end of 1998, ideas concerning the mapping of the knowledge required for projects was established. An initial pilot project to investigate the knowledge of 'Super Plastic Forming and Diffusion Bonding,' was carried out using these new ideas.

The project consisted of interviews with experts and was controlled by the construction of a map or visualisation of the knowledge. Interviews focused on exposing more of the visualisation. The tools used at the time were not well suited to this task. Tools from the Common KADS project (PCPACK) were available but lacked some very simple practical capabilities. For instance, in order to save a part completed map, one needed to exit from the program and restart it to carry on. During interviews with experts whose time was in great demand, it was important to firstly ensure that information collected was not lost and secondly ensure that interviews were efficient. The software made both of these requirements extremely difficult to manage. This was an early software tool which had been designed in an academic environment and not properly considered for use in a high demand practical environment.

In spite of these problems, the project was a great success and lead to several major changes in the way that BA Systems managed that particular work from a knowledge perspective. It was also suggested that these changes had a potentially high monetary value.

This project also delivered several critical items of information to the NWAIAG research initiative. Not least of these was the need to create a specific tool to support the method which would assist in the entire process and which would cater for the needs of security of information collected and also efficiency of the interview process.

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In 1999, collaborative research at the NWAIAG lead to a collaborative paper entitled 'Practical Approaches to Knowledge Management' (Gordon 1999). In this paper, several organisations clarified their positions on knowledge management and the results of a small survey were published.

3.2 The first purpose build tool

The lessons from KM1 and the lessons from the first mapping pilot lead to the creation of the first purpose built tool for SKA using Multimedia Toolbook. Not much survives from this tool because it was relatively short lived. It was however, used to carry out one experimental but focused study and one commercially based study in a utility company. Whilst visualisation was managed well, there were several problems which made its use impractical. The first was the need to keep swapping screens to enter different items during interviews, this turned out to be a source of confusion within the interview process. The second was that there would be a growing demand for intensive and rapid processing to be carried out which the multimedia tool was not capable of delivering at that time.

3.3 Changing Development Tool Language

The language used to develop a practical support tool for the method was becoming a barrier to progress. Prolog, C and LISP were considered as alternatives. LISP was ultimately chosen as the preferred development language and one of the main reasons for this was the flexibility it offered for the development test cycle. LISP's memory management capabilities also meant that the growing memory needs of a real life project could be met easily without the programmer or the user needing to predict knowledge base size in advance.
Most of the software development was carried out privately but still with the input and guidance of the Business team and Steering Committee. LISP has turned out to be a good choice because it has been able to cater for all of the growing demands of a continually evolving project.
The paper 'Focused Knowledge Management' (Godon 1997) recorded that the early Toolbook version or prototype knowledge study tool was used in 3 pilot companies in January 1996. This paper quoted a program of activity to develop early ideas as:

- A small programme of field trials took place in 3 companies using the prototype Knowledge Management Tool (Toolbook version). Feedback from these trials was presented at a meeting which took place in January 1996.
- A strategy meeting also took place in January 1996. This meeting developed an overall strategy for the project covering the development of an experimental Knowledge Management Tool and the development and dissemination of methodology.
- An initial meeting to develop a General Specification which could be worked to was held at British Aerospace, Samlesbury site on 20th February 1996.
- Several draft specifications lead finally to the internal publication of the general specification on 10th May 1996 (Gordon + 1996).
- An initial promotional event was held on 9th August 1996 and a first release of the new Knowledge Management Tool was made available to team members on that date.

This work followed on from KM1 (1994). A software demonstration system (tool) (the Toolbook Version) was released to collaborating organisations in March 1997 for testing and evaluation.
As the NWAIAG transformed itself into AKRI, the LISP based tool was able to develop alongside the method through several major knowledge study projects carried out in the early 2000s. By the close of AKRI, the research work was thought to be complete but it had gone hand in hand with knowledge studies which had delivered measurable benefits to the organisations which cooperated in them. These studies were reviewed in the paper 'Understanding the Human Knowledge Resource using Knowledge Structure Mapping ' (Gordon 2004).

All of the papers which came from this work can be found here: http://www.akri.org/papers/year.htm
At the close of AKRI, the research findings and the experimental tool were made freely available to all participating organisations.

4 A COMMERCIAL SOLUTION BUT NOT AN END POINT

In 2005, AKRI Ltd (Applied Knowledge Research & Innovation Ltd) was formed and part of its main goal was to take the ideas of SKA forward into a commercial version of KSM. A new tool was written in 2005 but this still used LISP (from LispWorks) as its preferred language following from the success of the experimental versions.

By 2006, a new version of the tool and an improved version of the methodology was used at a UK based Aerospace company to deliver a knowledge study for that company.

KSM was able to deliver the following support information for managers in 2006:

- A summary of captured lessons.
- A parameterised evaluation of the knowledge resource from experts.
- A clear map of the knowledge resource with text support.
- A parameter based analysis of the knowledge.
- A structure based analysis of the knowledge
- An evaluation of knowledge risk for the map based on expert opinion.
- A complete overall knowledge analysis using the combined information.
- A set of options (recommendations) for managers provided by human and rule based analysis.

The method and tool created between 2005 and 2006 could have been considered as a complete solution. However, customer feedback was deliberately collected from this and subsequent organisational studies and provided relevant and well targeted options for improving both method and tool. Such options range from the very simple such as the need to provide different colour coding to view analytical results so that the results would be compatible with corporate preferences. Other more significant (from a development perspective) management needs required for instance, the software tool to be capable of analysing the changes in knowledge risk etc, as project work continued and measures were put in place to reduce risk.

At each stage of improvement, new projects created further demand for additional improvement. Several such improvements will be outlined in order to provide a flavour for the method of change.

4.1 People and the Knowledge Resource

Although KSM maintained a strong link to its original ideal of showing the knowledge which was held and applied by people, one specific application lead to a realisation that in this case, managers would need to see exactly who the experts actually were. The tool was not able to provide this because its focus was knowledge needed rather than the individuals who held the knowledge.

A major upgrade of the tool allowed people to be added to the data held by the tool and then linked directly with the knowledge resource. This linkage also helped to clarify the meaning of the structure of the knowledge shown in at least one very direct way.

In one case, a manager stated that 'person a' was an expert in knowledge area 'k1'. The knowledge area 'k1' was supported by a learning or knowledge dependency structure which was constructed by asking the question that if a single person was an expert in 'k1' then what must that person already know in order to have that level of expertise.

The problem was that the manager admitted that 'person a' did not fully understand one of the prerequisite knowledge elements of 'k1' but was being put forward as an expert in 'k1'. The fact that the map had been constructed in line with a specific method related to learning or knowledge dependency meant that either

'person a' was not the expert claimed or that the construction of knowledge area 'k1' was not done correctly in line with the method. Clarification lead to the manager both withdrawing the claimed expertise assignment and also rethinking his view on expertise.

4.2 Knowledge Risk Reduction

In another specific case a long term project which involved a knowledge study was also associated with several developments to the Knowledge Structure Map over an extended period of time. At the early stages of the project the first map had delivered a knowledge risk assessment for the project and the manager in control had devised some measures to address these risks. Since continued development of the map was also required, it meant that the map was still very much active after almost a year of project work.

At this point the manager asked the reasonable question concerning how he could see if the measures which had been devised to reduce knowledge risk and make other knowledge improvements were actually working. The answer to this question could be found by re-evaluating the experts assessment of the knowledge items and comparing this with their original assessment from one year earlier. Since the tool was not able to carry out this task, two sets of assessment were created and then compared manually as two independent (*well separate rather than independent*) sets of results derived by the tool. Since the question was reasonable and the results were of value, the tool was updated so that it could carry out this analysis internally.

4.3 Time to Learn

One company was (is) interested in planning the human knowledge resource for a broad range of very long term projects. This meant that they were not only interested in what knowledge is required but how long it would take (approximately) for a person to gain the required knowledge. The Knowledge Structure Map is already organised by learning or knowledge dependency. Adding a learn time assessment to the tool meant that it could provide results directly through the map visualisation and managers could see the size of the knowledge structure involved. The tool could also work out the total learn time for the entire knowledge structure. These are simply estimates but are non the less useful in helping managers to plan knowledge provision.

4.4 Knowledge Needs within a Long Project

When the KSM method and the tool is applied to a long term project, it ultimately shows the entire (human based) knowledge structure required in order to deliver that project. One senior person involved was using other methods to look at how the project requirements for entire knowledge structure changed over time. He would have preferred that this changing requirement could have been viewed within the context of the map but was instead constructing time bar charts for each knowledge node on the map.

By investigating the company needs in more detail it was possible to build a 'when-needed' capability into the tool KST and integrate this with other existing features to actually provide much more than was originally requested. For instance, inspecting knowledge structure learn-time results as the map changed over time allows a user to see the length of learn time for any knowledge structure assuming that knowledge required at the current time is already known. This provided a dynamic knowledge planning inspection scheme to assist long term project planning.

4.5 Evolution to the current date

The four examples above show how the method and tool have been able to evolve and grow in service. They show how the direction of evolutionary development is adapted to the environmental needs of the

tool. They also show that the basic niche in which this method and tool live is still the same as it was originally. It is just better at doing what it does now.

This sort of improvement has driven the method even in its early research days. However, since the method and tool have been required to live in the commercial world, they have had to evolve more quickly and in larger steps than before.

Improvements between 2005 and 2013 have been considerable and are still taking place.

The main capabilities of KSM are currently (as of February 2013):

- The first and foremost benefit of a Knowledge Structure Map (KSM) is that it allows people who are responsible for an activity, to clearly see (and share with others) the knowledge involved.
- Analytical results are produced automatically by the supporting software tool (KST) and offer those individuals responsible, valuable expert based guidance.
- Options for Action are a core feature of Knowledge Structure Mapping (KSM) and a central support theme within the tool KST.
- The knowledge resource shown by the map is briefly but effectively described with clear and well organised documentation.
- An automatically produced web resource is just one way in which the data, the analytical results and the options offered can be made available to a wider audience.
- People, in the form of experts or in the form of capable individuals, can be added to the data which constitutes the map and associated with separate knowledge items and structures.
- It can be useful for managers to see a large common knowledge area which might exist between two separate business functional areas. This can offer decision support at operational and even strategic business levels.
- Knowledge resource risk can be both clearly defined and derived automatically by KST using data from the map.
- KST can produce change, growth or risk reduction data based on the automated comparison of current and previous maps.
- Visual assessment of learning time for each knowledge item can help managers to more effectively plan the availability of knowledge throughout a project.
- KST can present clear visual images which convey useful information about when items of knowledge are needed during the full lifetime of a project.

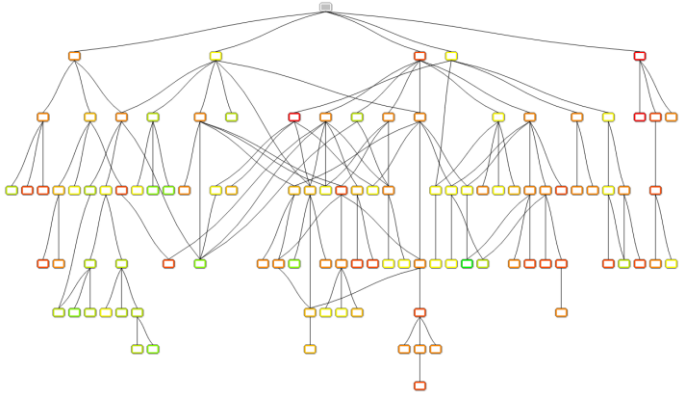

Figure 4: A Colour coded map screen from KST

Whilst these features are only briefly outlined here, they represent considerable development since the first commercial version of the method and tool was used in 2006 and an almost unrecognisable change since the original experimental system was first used in 1998. Yet it is still easy to see the basic framework of the original ideas, however much they have been developed, in the most recent versions of the method and tool.

5 CONTINUED DEVELOPMENT NOT SIMPLY ADDING CAPABILITY

Throughout the development of KSM, changes to the method and tool have been substantial yet KSM is still active only in the niche area for which it was originally envisaged. There have been pressures from some companies to add capability such as process planning to the tool. However, these have been resisted because they would mean that the tool KST would no longer apply directly to the method KSM. If allowed, such developments might mean that the tool would try to extend its reach too far, become too complex and ultimately fail to deliver benefit and improvement in its niche area.

A similar situation can be found with other software tools such as Microsoft WORD. The latest version of this word-processor is considerably different to the early DOS based word processor from which it developed. Software has two sets of pressure to change. One comes from changing customer needs, the other comes from technological or platform development.

The Knowledge Study Tool KST does not have the same pressure from platform change although this cannot be ignored. It does however, require continuous research and development in terms of method and niche capability. This is because the knowledge management based niche area is itself poorly defined as discussed earlier. Within this environment, the final capabilities of KST and to some extent the method KSM have not and have never been set. Yet, even though this is true, the niche area within which the method and tool operate have not and probably will not change.

Stated again, the method is a method to help those responsible for any activity to more effectively manage the knowledge which is held and applied by the people. The tool simply makes this task much easier.

6 CONCLUSIONS

At the outset, the original intention of this paper was to show how different the development of this knowledge management tool was from more typical software applications. However, the evidence stated for this conclusion only shows that it is not very much different after all.

The main points which do seem to stand out from this review of past work concern the role of research in the delivery of methods and tools for areas which are poorly defined. If a research, design, develop, deploy, strategy had been applied to KSM/KST, it would most certainly have failed. The main reason for the failure would be because it has only been in deployment that new issues to research, to design and then to develop have come to light. If the researchers and designers become detached from a project when it is deployed or even when it is developed, then success can only be guaranteed if the original designs are the final solution.

Topic areas within Knowledge Management are always likely to be poorly defined because of the very broad scope of the concept and the understanding that a well thought through definition of knowledge is not compatible with many application areas. Common KADS was developed as an alternative to an evolutionary approach and provides a set of tools for knowledge which are applied early in a development phase. This has proven successful in many cases but it is maintained here that because knowledge is difficult to define precisely and to the satisfaction of all participants, evolutionary change to knowledge based projects is inevitable.

This conclusion is drawn with respect to the development of KSM/KST but it could also apply to business projects which aim to understand and gain more benefit from a knowledge resource. This is likely to be true because it is only with the investigation of the knowledge resource that the real extent and utility of it becomes visible. In several business studies of knowledge, KSM has shown that the previous view of the knowledge resource used within a business area was wrong. In one particular case, which cannot be properly identified here, a specific area of knowledge was seen as an absolutely critical and a central part of an applied knowledge area. A detailed study of the knowledge using KSM was able to show that this critical knowledge area did not really feature in the application of knowledge or in the delivery of the

service provided. The critical knowledge was only added to the map at the insistence of the expert participants and even they could not show where to include it in the dependent structure. The critical knowledge was added to the map in such a way as to show that it was part of the entire business area whilst leaving it disconnected from the knowledge structure needed to deliver the service. In other words, I am a farmer, therefore I need to fully understand the details of the human digestive system.

The knowledge connected with knowledge based projects, particularly those focusing on human knowledge, needs to be studied before the full extent of its nature and utility begin to become clear. Those seeking business solutions and improvement need to be prepared to re-evaluate their pre-conceptions as the results of knowledge study become available. Managers should also be prepared to call for more knowledge study if initial studies show that the knowledge resource is not as expected. Project managers should not be in a rush to break the connection with research and design once development and deployment begin.

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