Designing digital prescribing: A new approach with branch diagrams

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ABSTRACT

Background: There is ample evidence that digital prescribing improves delivery of care and reduces harm, but there is not much guidance on how to design a solution.

Aims: This was written to provide a Blueprint to organisations creating electronic medication management solutions.

Methods: We created a full set of electronic prescribing Functional Requirement User Stories (FRUS's) to guide the design of a digital prescribing solution. The scoping exercise was completed delivering over 900 individual FRUS's in a structured manner. The design of the FRUS's began at the most general level and at each level each story was broken into its subsequent branching parts, in tree diagram style, to become progressively more detailed. All FRUS's needed, at a minimum, four levels of detail to be fully described to a degree adequate enough to build software for, with some needing up to seven levels to be fully described.

Results: The full content of the branching diagram of Functional Requirement User Stories (FRUS's) can be found at http://bit.ly/ElectronicMedsMan-FRUS. This approach to designing the requirements reduced the operational time for design by 75% and improving the completeness of the dataset by 47%. The full output link is provided to facilitate a further reduction in that time.

Conclusion: Using a branching, structured approach to designing the requirements of an electronic prescribing system was more accurate and more efficient. This approach can be used for other digital health solutions as well as prescribing. We have shared the output database free of charge.

1. Aims

Digital prescribing has been linked to a number of benefits, but most crucially a decrease in medication errors of several fold [1–3].

This work was written to provide a Blueprint to organisations working on rolling out electronic medication management solutions. The structure presented here for organising an exhaustive set of functional requirements - which is the essential first step to being able to implement a digital solution - had the effect of reducing the time taken to complete this exercise from 12 months to yield an incomplete list, to 3 months to yield a complete list. This meant a 75% improvement in digital transformation efficiency and a corresponding improvement in output fidelity. We compare the branching diagram approach to other structures in the Discussion.

The detailed content of the branching diagram of Functional Requirement User Stories (FRUS's) can be found at http://bit.ly/ElectronicMedsMan-FRUS. These are provided to enable a further reduction in time spent on this phase of electronic medication

management digital transformation by ensuring that teams need only locally customise a generic example, rather than create all content from scratch.

2. Introduction

The Global Digital Exemplar (GDE) programme was created by NHS England to help digitally develop the public healthcare services provided in England and the UK [4]. The programme is designed to enable knowledge sharing via the process of 'Blueprinting' from learnings taken from digitally advanced trusts and their Fast Follower trusts [5,6]. This was to be done with a particular focus on the implementation of integrated Electronic Patient Records (EPRs).

The EPR Liverpool (EPRL) programme is part of the digital transformative working taking place at the three Liverpool NHS Trusts of; Royal Liverpool and Broadgreen University Hospitals NHS Trust, Aintree University Hospital NHS Foundation Trust, and the Liverpool Women's NHS Foundation Trust [7]. The Trusts currently use a fully

digital electronic prescribing and medicines administration (ePMA) product, and are working to move to a fully integrated ePMA product, connected to the EPR [7].

As part of this, an end to end scoping exercise was completed in order to map out, in a structured and detailed form, what the minimum functional requirements for an ePMA would be. The outputs were written such that they could be structured as a branching diagram of user stories to be used in Extreme Programming (XP) [8], should an XP approach to technology development and implementation be planned. The standard XP user story format being, 'As a [role], I want to [do an action], so that I can [achieve an outcome]'. The format of the requirements was written such that the summary document could be used throughout the end to end digital lifecycle. This cycle includes procurement, design, configuration, implementation, and testing of an integrated ePMA product. This structure was used to facilitate project management, progress tracking, documentation, and audit trails.

In support of GDE Blueprinting [5] both the process of, and the outputs of this work are published here. This includes the supplementary document outlining the specific FRUS's freely available at http://bit.ly/ElectronicMedsMan-FRUS. We understand that each organisation will work in its own way and will have its own needs for a digital medicines management system, so this work is not intended to be used verbatim between organisations. What we do intend to provide is, both an approach to completing this exercise, and an example FRUS output document to use as a guide that can be adapted to individual sites as needed. The described approach and examples gives a steer on how to commence this work in local organisations, whilst still giving plenty of room for customisation. The design of this document is intentionally technology supplier agnostic. This piece of work is intended to be used alongside a similarly structured document of digital Non-Functional Requirement User Stories (NFRUS), which is not covered in the scope of this publication.

3. Methods

The scoping exercise was completed delivering over 900 individual FRUS's in a structured and branching manner. The design of the FRUS's began at the most general level and at each level each story was broken into its subsequent parts to become progressively more detailed. All FRUS's needed, at a minimum, five levels of detail to be fully described to a degree adequate enough to build software for, with some needing up to seven levels to be fully described.

The schematic in Fig. 1 shows how each FRUS was made up of progressively more detail at each level;

The full set of FRUS's were constructed around eight main principles. These principles were drawn from theories behind Lean software

development [9], DevOps [10], digital transformation [11], healthcare informatics [12], and Agile project management [13]. The principles were then tailored to be appropriate to the healthcare setting. In the Methods of this publication we will explain how we achieved each of these eight principles. In the Results we will outline the detailed headings of the FRUS's and provide the example output document of over 900 individual FRUS's.

The creation of the full set of FRUS's was based on the following eight principles;

● Outcomes Focussed
● Individually Pass/Fail Testable
● Logically Structured
● Mutually Exclusive and Collectively Exhaustive
● Tracked and Auditable
● Multi-Disciplinary
● True to Life
● Complementary to Non-Functional Requirement User Stories (NFRUS)

3.1. Outcomes Focussed

Each FRUS was written such that it described what was trying to be achieved without dictating how it should be achieved e.g. "it should be made clear to the end user when a duplicate therapy is being prescribed" rather than "an alert should pop up on the screen if a duplicate therapy is prescribed". Writing in this manner ensured that those closest to the creation of the software (the development and user experience design teams) had the freedom to achieve the required outcome in the most effective way. Avoiding prescriptive descriptions of an FRUS also avoided the problem of a feature marked as complete when it had achieved the letter but not the spirit of the description. To use the previous example, this might be when a small and easily missed alert popped up in the corner of the screen to inform the user that a duplicate therapy had been prescribed.

3.2. Individually Pass/Fail Testable

Describing each FRUS in a manner that avoided ambiguity ensured that there was immediate consensus on whether the requirement was met by the technology or not. This extended into being immediately able to identify whether a requirement was met by the configuration, testing, and user acceptability assessments. An ambiguous FRUS might read "software should ensure safe prescribing of warfarin", which will be interpreted differently by both software developers and clinicians. Whereas a statement such as "software should allow for prescribing of
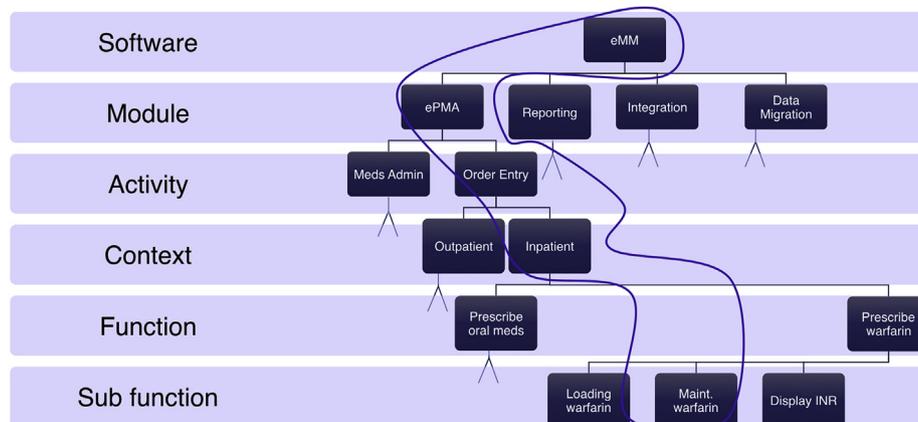

Fig. 1. The progressive breakdown of each FRUS from most general description to most specific. The circled pathway outlines a single FRUS. In total there were over 900 distinct FRUS's.

warfarin without specifying all future warfarin doses" and "software should ensure previous INRs are visible at the point of prescribing warfarin" describes the meaning behind 'safe electronic prescribing of warfarin' in a specific and quantifiable manner. In addition to this, FRUS's written in this manner increase the efficiency of electronic software development and deployment as it is not necessary that teams building this requirement have highly skilled domain knowledge in order to deliver it so it is possible to handoff development and deployment to those with less specialised training.

3.3. Logically Structured

Common approaches to creating a detailed set of FRUS's for digital medicines management are to write them as a list, or lists in categories [14,15]. This invariably results in missed information as it is difficult to think about every detail in such a large domain. Beginning first at the largest categorisations and progressively dividing them into their component parts as indicated in the above tree diagram in Fig. 1 is far easier for individuals to compute. The direction of this approach is fundamental, because it is tempting to think of the most detailed FRUS's immediately. However it is important to first start at the most general level and progressively divide down as it ensures that there is confidence at the end that no part of digital requirements had been missed. This also allows for an easier audit trail if the database of requirements ever needed to be interrogated.

3.4. Mutually Exclusive and Collectively Exhaustive (MECE)

The MECE principle is taken from management theory of business process mapping wherein "the optimum arrangement of information is exhaustive and does not double count at any level of the hierarchy" [16]. By beginning with the most general description of functions and progressively breaking this down into ever smaller and mutually exclusive categories, we could be confident that no part had been missed out (exhaustive) but also that no part was described in multiple places (mutually exclusive) which otherwise could have resulted in conflicting software decisions and repetition of work.

3.5. Tracked and Auditable

The structure of the completed digital medication management FRUS document is such that it can be used as a checklist at every stage of the software lifecycle including; procurement, design, configuration, testing, and user acceptability assessment. Using a branching logical structure ensured that future audits of decision making and design in software could be completed easily.

3.6. Multi-Disciplinary

Most digital medicines management solutions rely heavily on pharmacist input for their design, build, and implementation. However even a single medication for a single patient journey involves a number of different disciplines, as illustrated in Fig. 2.

As part of the design and validation of our complete FRUS set for a digital medicines management solution, we internally defined quorate decision makers to include representatives from; pharmacists, pharmacy technicians, doctors, nurses, midwives, medication business intelligence reporters, and management.

3.7. True to life

The validation of this set of digital prescribing FRUS's was considered incomplete without confirming their accuracy live, by engaging with practicing clinicians and shadowing patient facing encounters in order to correctly understand whether the software was robust enough for real world application. In particular, live visits were made to places with atypical medication management, such as the dialysis unit, intensive care unit, and delivery suite, as well as more standard medication management areas such as the pharmacy dispensary, and the inpatient medical wards.

3.8. Complementary to Non-Functional Requirement User Stories (NFRUS)

The focus of this piece of work was specifically on the functional aspects of an electronic medication management solution. However no digital solution is complete without addressing the non-functional requirements. This includes software speed, intuitiveness, readability, data integrity, and maintenance of audit trails. A detailed set of NFRUS's for digital medication management is out of the scope of this publication and will be covered separately. We recommend that the set of FRUS's for digital medication management be used alongside a similarly structured set of NFRUS's.

4. Results

The full set of publicly available digital medication management FRUS's created by this work can be downloaded at http://bit.ly/ElectronicMedsMan-FRUS. The impact of this approach was a reduction in the time required to complete the entire set of FRUS's from 12 to 3 months. Using list-based and unstructured methodologies only 68% of requirements were identified, with this structured methodology 100% of requirements were identified.

The output was segmented into up to seven levels. Each individual FRUS took a minimum of five levels to completely describe, some required six and some required seven levels. Table 1 shows the headings of each of the levels, the definition, and the number of unique values at each level.

The breakdown of levels 2 and for the ePMA section of level 3 (Module and ePMA Activity respectively) is outlined in Table 2 and Table 3 below. For the detailed content of the subsequent levels, full documentation can be found publicly available at http://bit.ly/ElectronicMedsMan-FRUS. Significantly, the full document includes a section on defined areas out of scope for the project.

5. Discussion

5.1. EMM landscape in context

There is increasing evidence that electronic prescribing records result in reduced medication errors [1–3,17,18], improvements in legibility [1], more standardised treatment [3,17,19], and a reduction in time spent on non-value tasks such as re-transcribing drug charts [3]. Much of the literature around electronic prescribing has been written to measure and report on the before and after benefits of rolling out digital prescribing, or to present novel and innovative ways in which an electronic prescribing system can improve patient care [20–22].

The above is certainly true, and it contributes significantly to creating business cases and making the argument for change. However, beyond the pre-sales business case design and procurement stage [23], there is still little in the literature in terms of 'how-to' recipes for design and implementation of electronic prescribing systems once the business case is complete. Often vendors are relied upon to provide the detailed guidance on implementing systems. While vendor cooperation is vital to success, ultimately implementing sites are the ones with the greatest incentives to ensure that the implementation is done to suit their needs.

5.2. FRUS's versus patient journeys

One approach to structured outlines of FRUS's for electronic prescribing has been to use patient journeys. This is an approach that has been used by the Scottish HEPMA [24] amongst others. The advantages of patient journeys is that the transitions between each step is stress
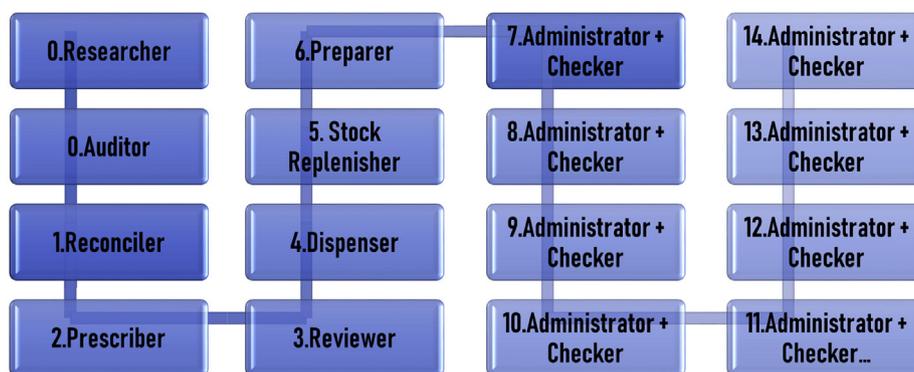
Fig. 2. Disciplines involved in a single-medication-single-patient journey. The 0's indicating the pre-patient steps of the journey.

tested, and that the stories create a realistic true-to life picture of what is trying to be achieved.

The disadvantages are that patient journeys allow for only a limited examination of a set of requirements. Using this database of FRUS's as an example, the number of permutations that can be created from 910 FRUS's are 2.5×10^{2299} (using a $_{910}P_{910}$ permutation formula), and this assumes no repeated steps. Even conservatively assuming that only 10% of these permutations are clinically possible, that would mean a very large number of patient journeys were required to test all possible combinations. Patient journeys may also fail to cover non-patient facing FRUS's, such as reporting, and NFRUS's, such as intuitive design. The expectation is that using a branching diagram approach to outlining FRUS's ensures that the list is indeed exhaustive and that each patient journey transition is covered in one of the FRUS's itself.

Nonetheless using a branching tree diagram set of FRUS's does not preclude the individual steps being arranged in different ways to create patient journeys. This is in fact, encouraged to facilitate training and testing.

5.3. FRUS's - branching trees versus lists

Another approach that has been taken to detailing FRUS's of electronic prescribing systems has been the, Categorised List method [14,15]. This involves breaking the parts of the EMM solution into different categories, such as order entry, medication administration, clinical decision support, etc - similar to Level 3 of our FRUS tree diagram. From there all detailed individual requirements in that category are listed within it [14,15]. This is not an unreasonable approach, but the lack of structure makes it harder to ensure everything is covered. Indeed, when we moved from the Categorised List approach to the FRUS branching tree approach there was a 47% increase in the accuracy of the dataset, from being two-thirds complete, to being fully complete.

5.4. Operational and reproducibility benefits of this approach

The Blueprint for our FRUS's can be found and downloaded free to use.

http://bit.ly/ElectronicMedsMan-FRUS. This document is shared to support providers by providing them with a checklist and structure around which to organise themselves when implementing an electronic prescribing system. We are proponents of this approach due to the positive operational impacts it had on the roll out. In addition to this, the electronic health record enterprise software lifecycle generally follows a timeline roughly consistent with; business case, procurement, design, configure, test, implement, optimise. We have written these FRUS's such that they can be used at any stage of this lifecycle.

While the set of FRUS's is focussed around electronic prescribing, the approach itself is not and can be used in any other part of Digital Health. At present we are piloting the use of this approach in developing a digital Operating Theatres module.

6. Conclusion

Using the described tree diagram structured approach and principles allowed us to reduce the time and increase the accuracy of a full set of FRUS's for electronic medication management significantly. We have created a generic format of our work that can be locally customisable to different sites to support a more efficient approach to digital transformation in electronic medication management.

Acknowledgements

Table 1
Digital medication management FRUS's levels. From Level 1, the most general and all-encompassing level, to Level 7, the most detailed level. At a minimum all FRUS's needed 5 levels of detail to fully describe.

Level Number	Level Name	Level Definition	Unique Values
1	**Software**	The overarching tool for electronic prescribing. *E.g. Integrated Electronic Patient Record*	1
2	**Module**	The part of the software that is required. *E.g. End user medication prescribing and administration, back-end analytics, or integration interfaces*	5
3	**Activity**	The cluster of tasks being achieved. *E.g. Order entry, medication administration, or business as usual reporting*	18
4	**Context**	The aspect of the patient journey being covered. *E.g. Inpatient, operating theatres*	71
5	**Function**	The specific outcome to be achieved. *E.g. Record administration of an intravenous infusion*	346
6	**Requirement**	(If applicable) Further detail on the specific outcome to be achieved. *E.g. Record the start of an administration of an intravenous infusion*	439
7	**Subfunction**	(If applicable) Further detail on the specific outcome to be achieved. *E.g. Identify the user recording the start of an administration of an intravenous infusion*	175

Table 2
Level 2 - Module. Description of the breakdown 'Level 2' of Module in digital medication management FRUS's.

Description	Definition	Number of FRUS's
ePMA	End user electronic prescribing and medicines administration	826
Integration for Integrated EPR ePMA	ePMA interfaces with other software systems	13
Migrating Data	Archiving of medical records from legacy software systems and transfer of data into new system	5
Reporting and Analytics	Business intelligence functions required as part of business as usual	64
Scope	*This category was used to highlight what was out of scope of the FRUS's and provide a reference for developing a product roadmap*	*N/A*

Table 3
Level 3 - Activity: ePMA. Split of Level 3 FRUS for Activities in ePMA Module.

Description	Percentage ePMA FRUS's
Medication order entry	54%
Clinical decision support	12%
Medication administration	11%
Pharmacy review	9%
Medication history reconciliation	5%
Medication chart review	4%
Business continuity set up	4%
Business-as-usual preparation	2%

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.compbiomed.2019.103388.

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