Proposing a Gamified Solution for SMEs' Use of Messaging Technology in Smart Manufacturing

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Abstract. Small- and medium- sized enterprises (SMEs) face exceptional challenges in implementing smart manufacturing solutions. Specifically, SMEs often struggle with understanding advanced technologies well enough to implement them and reap the benefits. In this paper, we discuss one specific instance of this problem, namely implementation of data standards for effective business-to-business communications. We propose a possible solution to aid in lowering barriers for SMEs to access and apply technologies for data standardization, a vital part of effective business-to-business communications. Our solution takes a gamified approach by working to conceptualize the SMEs' data into a story with fill-in-the-blanks, similar to a Mad Lib[TM]. We believe that the development and implementation of this tool would provide numerous benefits including, but not limited to, boosting morale, making new technology and standards more approachable, and improving the learning experience.

Keywords: SME, smart manufacturing, data standards, gamification, Mad Lib.

1 Introduction

Data and the exchange thereof is at the very core of digital transformation and Smart Manufacturing (SM) [1]. Data and information are used in a variety of applications and use cases, from high-fidelity machine tool sensor data to qualitative inspection data to business process data such as invoices along the supply network. To ensure efficient and effective exchange of data and information, as well as semantically correct interpretation of the information, a variety of information models and data standards have been developed and widely adopted. For example, Open Platform Communications / Unified Architecture (OPC UA) is a communication protocol for industrial automation, while the Open Application Group Integration Specification (OAGIS) focuses on data exchange for enterprise business processes, such as supply chain information.

The utility and benefits of standardized data formats are commonly accepted; however, the development, industry or organizational setting, and especially integration poses several challenges that hinder widespread adoption. Specifically, small- and

medium- sized enterprises (SMEs) are struggling to match larger manufacturers in the use of advanced technologies and standards. In this paper, we propose a solution to one specific instance of this problem, namely barriers associated with SMEs adopting standardized data messaging within supply chains.

In the background section, the paper discusses messaging standards for communication, and the struggle of SMEs. Next, we describe gamification and how it relates to addressing the barriers faced by SMEs. Then, we propose an approach to effectively reduce these barriers faced by SMEs. Finally, we summarize our work, provide future work, and discuss limitations.

2 Background

2.1 Smart Manufacturing in SMEs

SMEs, representing a diverse set of organizations, are considered the backbone of US manufacturing and an integral part of most supply networks. The issues discussed herein do not apply to all SMEs and are generalized.

Despite the number and importance of manufacturing SMEs in the economy, their perspective is not always considered regarding the adoption of SM technologies and related business practices [2]. SM aims to help companies become more competitive by capitalizing on the three pillars: connectivity, virtualization, and data utilization [3]. The growth of SMEs, and their ability to contribute to society, may be hindered when their perspectives are overlooked. This may adversely impact the growth of the economy and the creation of globally competitive digital supply networks. A recent study on the state of SM adoption in manufacturing SMEs [4] found a distinct difference between how SMEs approach SM and how larger, international enterprises develop their SM strategies. These differences affect how effectively SM can be supported across different businesses. Table 1 highlights a selection of key differences between SMEs and large manufacturers that present barriers for the adoption of SM at SMEs and also for the efficient collaboration with mixed supply networks.

2.2 Communication, Interoperation, and the Plight of SMEs

In supply chains, communication supports joint work. Examples include alerting a supplier that more of what it supplies is needed, replying to the requester that what is requested is on its way, and asking for payment for doing so. The party making the request for supplies might be an original equipment manufacturer (OEM) of a complex product. These OEMs deal with many suppliers and likely have complex production plans. To orchestrate the work of its many suppliers and ensure smooth operation of its production lines, OEMs have typically sought uniform, efficient processes. Third parties, including logistics providers and government agencies involved in trade, also under the pressure of dealing with many customers, have followed suit [5]. Over several decades, a rough consensus regarding processes and terminology has emerged and has been encoded as the industry's best practice in messaging standards. These standards

include Electronic Data Interchange (EDI) emerging in the 1980s, OAGIS [7] in the mid-90's, and the Universal Business Language (UBL) [6] in the early 2000s.

More recently, OEMs and upper-tier suppliers, most of whom have benefited by implementing messaging standards, have encouraged use of the standards among the smaller firms with which they do business. Standardization at the lower tiers promises to further improve the efficiency of everyone involved. Unfortunately, messaging standards involve complex information technology, and SMEs, owing to their size, are unlikely to possess the skills needed to implement them. Since the use of information technology in this use case does not concern revenue growth, it seems reasonable to conclude similar to Mithas et al. [8] that the cost of implementation may chip away at the SME's profitability. Further, a 2019 study noted that despite a booming economy, nearly two-thirds of small companies cannot cover their expenses and that SMEs are spending far less on research and development (R&D) than they have in the past [9].

Table 1. Selected key differences between SMEs and large manufacturers regarding adoption of SM (adapted from [2] – please see reference for complete list).

No.	Feature	SME	Large Manufacturer
1	Financial resources	Low	High
2	Software umbrella (incl. data analytics)	Basic	Comprehensive / integrated
3	Research & development	Low	High
4	Standards considerations	Low	High
5	Alliances w. universities/research institutions	Low	High
6	Important activities	Outsource	Internal

2.3 Barriers to Adopting Standardized Messaging for SMEs

We can observe a mix of challenges that stem from i) difficulties within the technology adoption process itself, and ii) SMEs' internal factors as described in the previous subsection. There is no clean-cut line differentiating the two and they amplify each other.

SMEs have a general disadvantage compared to larger organizations when it comes to adoption of tools, methods, or standards that require substantial resources and/or specific domain knowledge [2]. While larger organizations have the overhead to provide such dedicated support, most manufacturing SMEs do not [10]. This is particularly troublesome in the IT space, where a dedicated, well-staffed IT department is common in larger organizations, while SMEs often rely on outsourced individuals to support their efforts [2]. Hence, SMEs are often left with limited options, such as to i) acquire/build the knowledge inhouse; ii) outsource implementation, integration, and maintenance of solutions to third parties; or iii) rely on solutions that are user friendly and do not require domain knowledge beyond what can be expected of a SME.

It is likely that SMEs find the messaging technology described in Section 2.2 to be arcane and daunting [4]. Conversely, SMEs are quite likely to maintain much of the essential information about their business processes in the form of spreadsheets [2]. To

communicate with their large, IT-capable business partners, using a common messaging technology, SMEs must determine what part of their spreadsheets correspond to what parts of the standardized message form. This 'mapping' of information, the key task investigated in the paper, presents challenges for SMEs.

To-date, much of the support material and documentation of messaging standards are aimed at users with a specialized background in, and arcane knowledge of, messaging and mapping - mostly found in larger organizations. Hence it is no surprise that there is a disconnect between the adoption rate by SMEs and large organizations. Besides the IT resources and domain knowledge, further barriers that hinder SMEs from engaging in the efforts include production quantity (that might not 'require' automation of messages yet due to small quantities), diversity and number of customers and suppliers (diversity of messaging formats to deal with), state and integration of their IT systems, and language barriers and customs processes (for international business).

In essence, to fully address this problem and close the adoption gap between SMEs and large organizations, we need to understand and reflect on the stakeholders' requirements. Future methods will not succeed if they overwhelm SMEs with additional costs or complexity. Solutions to the mapping tasks need to be user-friendly with applications that reflect their reality, for instance by aligning with the use of their own spreadsheets, and thus leveraging tools familiar to SMEs. In the following sections, we propose the use of motivational affordances from the gamification domain to close the gap and make the goal of SMEs adopting advanced messaging standards more attainable.

3 Gamification as a Foundation for the Proposed Solution

3.1 Overview of Gamification

Gamification is "the use of design elements characteristic for games in non-game contexts" [11]. Common applications for gamification include education, training, and healthcare. Although little research is evident in manufacturing and business operations, gamification has expanded into numerous industries in recent years [12].

Fig. 1. Key motivational affordances of Gamification (based on: [13])

The game design elements depicted in Figure 1 are occasionally referred to as motivational affordances. Often, by applying these motivational affordances in a non-game context, the situation may be considered gamified. However, with no clear lines drawn, this decision is ultimately left to the designer. It is common for a design to include multiple motivational affordances.

In sections 3.2 and 3.3, the opportunities, challenges, and limitations included are discussed specifically due to their relevance to the SMEs' challenges described above. Additional opportunities, challenges, and limitations may be prevalent with general implementations of gamification; however, we believe the following are the most applicable instances for the use-case discussed in this article.

3.2   Opportunities with Gamification

We believe that gamification presents an opportunity to address the identified problem by making the performance of complex cognitive tasks more tractable. Gamification provides opportunities for both solution designers and users. For the solution designer, gamification provides guiding principles. The objective is to create a more intuitive experience for the user of the tool, aiding in its adoption and improving the user's ability to perform a complex cognitive task. For instance, "mapping" information from a SME's spreadsheets to a standards-based message. Further, an intuitive gamified experience which helps a user learn how to implement a new technology is likely to reduce the number of questions about its use, and thus requires less technical support.

New technology is used hereafter to refer to technologies, solutions, or systems that are new to the implementing entity and present an adoption challenge, with standard-based messaging as the focal instance in this paper.

For the user, gamification provides a morale-boosting approach to what is likely a daunting new technology. With the boost of morale, the learning and implementation of this new technology would seem less threatening, more attainable and 'fun', and makes the task worth doing. With majority of gamification affordances, they provide the user with a means to assess progress, and thus a sense of accomplishment. A key opportunity of gamification is that it makes challenging and complex tasks, such as adopting a new technology feel more attainable. Ultimately, the proposed solution in this work is meant to lower the barrier for SMEs to realistically implement data standardized messaging systems on their own. We believe that gamification significantly supports this transition for both the designer and user.

3.3   Challenges and Limitations of Gamification

Although gamification provides many opportunities to address the problem discussed in this article, it also presents some limitations. To implement gamification, significant time and effort is often necessary beyond that which is required for developing a conventional user interface. The development of the gamified tool likely requires multiple-disciplinary interaction for development and implementation. Additionally,

designers must consider the balancing act between sufficiently developing the gamification so that it is user-friendly, while also not over engineering the solution which might lead to users spending time on tasks with little value-add. In a few instances, gamification can be seen as childish or not feel like a real solution to the problem.

4 Mad Lib: Gamification of Mapping Diverse Data to Standards

4.1 The Proposed Solution Explained

We propose the use of a Mad Lib, a word game where a story is completed by filling in blanks [14], to translate information from raw data (e.g., custom spreadsheet-based invoices), to a Mad Lib for validation, then to standardized data (e.g., OAGIS) (see Fig. 2). The process to use the Mad Lib will be as follows: (a) user (SME) will open their data source, likely in a spreadsheet, (b) the user will reference to a specific column of their Spreadsheet to complete the Mad Lib story, (c) after completing the Mad Lib, the user will read the Mad Lib like a story to validate that the information was referenced correctly, and (d) the tool will establish a connection between the initial spreadsheet through the Mad Lib to the standard's message form. We propose the combined use of human validation for conceptual dependencies and computer-aided validation for formatting such as numerical values, currencies, or text. By using this tool, SMEs will set up the connection for necessary linkages to appropriately implement the data standard without requiring the knowledge of the data standard.

Ideally, we anticipate this tool to be used once to set up the necessary connections for identical sets of information and/or each customer-supplier relationship; subsequent usage would reuse the knowledge about spreadsheet structure gained in the initial use. However, it is assumed that each different supply chain process (e.g. invoicing vs. advance ship notice) might require its own script, as would non-routine tasks. We also anticipate a multi-time use option for rare instances which do not require reoccurring connections. In general, the determination of this tool to be a one- or multi-time use tool will be made clear throughout the development process based on stakeholder feedback and programmability.
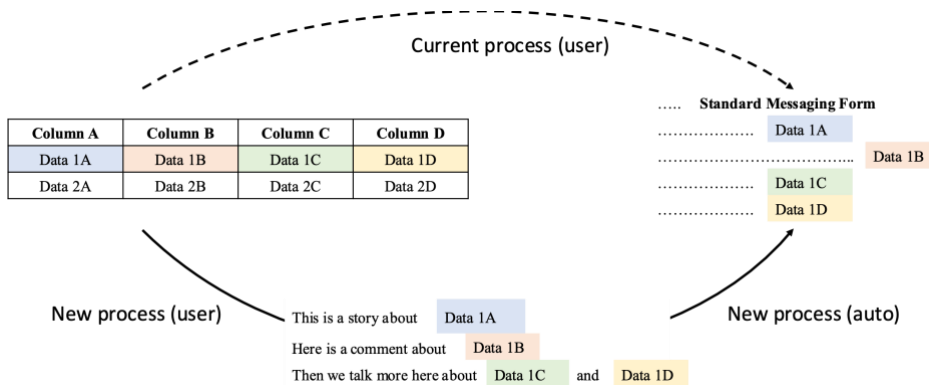
Fig. 2. Schematic of integrating gamification in mapping process via Mad Lib.

This proposed solution can be classified as gamification because it utilizes the story/theme, immediate feedback, and challenge affordances. These affordances are clearly involved in the Mad Lib solution because (a) a Mad Lib builds a story, (b) immediate feedback is provided to the user in the validation step wherein they are able to see if the story of their data is clear, and (c) the ability to conceptualize data from a data source to a story is likely to be challenging for new users. Additionally, we may consider adding extra affordances to enhance the user experience, such as badges, points, and leaderboards. We anticipate that these extra affordances may improve user enjoyment and excitement to use the tool, and thus the motivation to implement the standardized messaging technologies.

4.2   Efficacy of Mad Libs' use by SMEs

Gamification provides opportunities to make new adoptions and implementations more widely accessible, by lowering the initial entry barriers of incorporating new and advanced technologies for SMEs. The Mad Lib provides a means for the SMEs to conceptualize data information into an easy-to-understand and intuitive format - a *coherent and sensible story*. Additionally, the tool encourages valid mapping, through a user-friendly validation step, which can be used, and in some cases is required, for B2B transactions. Most importantly, this tool will allow SMEs that use spreadsheets to use standard messaging techniques in communications with their business partners.

As with most proposed early-stage solutions, the potential challenges are difficult to anticipate and predict. From the viewpoint of initial implementation for a given SME, the formatting of the spreadsheets (or lack thereof) may impact the ability of the tool to be utilized as intended. In some cases, the spreadsheet may be at a point where it may be too difficult or time-consuming to reformat, that utilization of the Mad Lib can be considered unreasonable. We propose that initially the SME could validate the completed Mad Lib simply by verifying that the story produced makes sense. This however presupposes contextual expertise and knowledge and may introduce error and bias into the process. Another potential pitfall of the proposed Mad Lib solution is that the story line (script) may not apply in a given context. An example of this (outside our area of focus) is that scripts for fast-food and full-service restaurant scenarios differ; in fast-food restaurants you order before sitting down to eat. Additionally, most of today's typical messaging standards are built to accommodate a large amount of information. Including all of this information in a Mad Lib would be overwhelming and unnecessary. Thus, while developing the Mad Libs, we must assess the appropriate amount of information to include in each story line and consider the definition and intended ontological sense of each 'blank' in the story. We plan to address this by clearly defining each blank with a pop-up window, however this may still allow for human error in the process.

5   Conclusion, Outlook, and Limitations

In conclusion, we suggest the development and implementation of a Mad Lib-esque solution to lower the barrier for SMEs that are required by their business partners to use standards-based messaging. This Mad Lib will serve as a gamified method that allows SMEs to tell a story using data they typically manage in spreadsheets. The Mad Lib tool will then map that information into the standard message form which is compatible with technologies used in business communications. The tool will be tested with SME users in processes such as invoice processing.

Future work for this research includes expanding on a prototype for development of software for the proposed solution. We will begin this by investigating common business-to-business (B2B) communications, such as an invoice. Using the OAGIS messaging standard, we will develop Mad Libs for common B2B communications. After thorough development of an initial prototype and building out the initial idea presented in this paper, we will implement and test the prototype of the new gamified tool. Iterations and improvements of the tool will be completed throughout the process as necessary. Throughout the development, implementation, and testing phases, we will work closely with SMEs to receive feedback in order to develop a user-friendly and user-centric solution.

The primary risk involved with this research is the scant exploration of the proposed solution. While the solution has been discussed amongst the authors in detail, it has not yet been proposed to end-users, SMEs. To address this limitation, we started a Delphi study to better assess the needs of SMEs in today's SM environment.

Acknowledgements & Disclaimer

Certain commercial software products are identified in this paper. These products were used only for demonstration purposes. This use does not imply approval or endorsement by NIST, nor does it imply these products are necessarily the best available for the purpose.

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