Fall 2021 CS 497 Capstone Project
Developing a Connected Knowledge Management System to Increase Workforce Capabilities

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Abstract

Technological innovation within production environments for technical manufacturing and maintenance operations is a field of study that has encountered many gaps between the vision of largely automated intelligent systems, and systems that continue to rely on a mostly human workforce. This study is intended to fill in that gap by proposing a system designed to increase capabilities and enable the human workforce by means of technological innovation and the use of existing modern enterprise cloud models alongside mobile and other thin-client computing. To achieve this, comprehensive information and knowledge management systems in such environments is an essential factor for a successful and efficient workforce. Such a network can also be leveraged by developing a persistent communication platform that can enable subject matter experts in the field to coach workers in real-time and help them work through difficult and complex scenarios, thereby enabling success and efficiency. Success and efficiency can be measured in terms of productivity, quality, and safety of operations. The motivation behind the research is that a workforce equipped with smart knowledge systems is easier able to handle broader roles and effectively better utilize cross training techniques. The contribution is that the concept design proposed in this paper may be adopted by organizations that seek to increase the capabilities of their own workforce.

Keywords: Knowledge, Management, System, Workforce, Capabilities.

1. INTRODUCTION

Fully automated manufacturing and maintenance systems has been a goal of the modern era which have left gaps in business plans that would be better addressed by instead investing in computer-based knowledge management systems geared towards augmenting workforce, knowledge, skills, and human decision-making abilities, which results in increased quality and efficiency.

Current computer workforce skills in regard to computers, technology, and mobile devices are something that should be utilized to address this goal. People already know how to use mobile phones and computers. Therefore, there is minimal re-training required to make this transition. With 85% of Americans owning Smartphones and 72% of working age Americans using Social Media (Pew Research Center, 2021), most of the modern workforce has a sufficient understanding of how to operate mobile and web-based computer systems, and therefore these existing skills and the computer systems upon which they are based on should be leveraged for developing better computer-based knowledge management systems that augment workforce skillsets for the purpose of improving quality and productivity. Currently, training and Knowledge Management Systems for skilled and high-tech manufacturing as well as field maintenance personnel lack a cohesive technological framework that integrates well with the way in which modern technology can be leveraged. Many of the computer systems currently that had been designed for this purpose either rely on aging, and outdated models with poor UX/UI interfaces or are altogether not leveraging current computer and web-based technologies. Adoption of computer systems and modern design practices in a system that supports knowledge applied to operations can ultimately result in Quality and Performance improvements to operations.

The problem and gap that this paper seeks to address are that improvements can and should be made to workforce knowledge management by developing a unified platform for knowledge management by leveraging existing enterprise cloud services, including data and user-based feedback loops, paired with proper UI/UX front-end design philosophies for the end-user and therefore have the ability to further integrate workforce training and skills enhancement improvements based on strategic data acquisition strategies and business process interoperability with computer systems as well as a feedback and a design philosophy that adapts itself to applicable usage in specific operations.

Problem Statement

In cases where AI and automation are inconceivably difficult, improvements to workforce training via Enterprise Cloud services and proper human-computer interaction techniques are the appropriate logical step for improvement. Unfortunately, firms that rely solely on traditional foundational training methodologies as the primary means for integrating new hires into the workforce, training re-classified workers, or simply improving current skills lack in efficiency and impact and therefore can't adequately train practical skills in a context that is based on the situations that occur in the field or the shop floor. Due to this lack of a unified training platform, the time and value spent training results in a waste of time and resources. This paper advocates for a digital platform to solve that problem which relies on two main objectives:

1. Using (enterprise) cloud-based and user interface best practices and data management systems, modularize Training for processes, Embed the modules into digital Content Management Systems / Knowledge Management Systems, During Training orient the Learning client path towards the understanding of also how to navigate the knowledge management systems to find the answers. Do this by using the system itself as the platform for training delivery and allow the system to be the backbone of persistence reference material.
2. Employ a team of dedicated and persistently connected Workplace Coaching experts that are enabled by the Knowledge Management System to fill in the gaps.
3. Plan Feedback loops into the training and application of skills process to drive improvements to the training and reference material.

Motivation

Much of the recent advice on manufacturing has been geared towards automation and AI with the intent of automating entire manufacturing processes. While there are many feasible and practical applications for complete automation and AI in manufacturing systems, many areas specifically those that require greater complexity of processes requiring fine skills and complex decision making are not ready for full automation, therefore in those cases augmenting the knowledge and skillset of technicians would be a better investment and use of cloud software systems at least in the near term.

A workforce equipped with smart knowledge systems is easier able to handle broader roles and effectively better utilize cross training techniques. In effect, they become more Agile. Hopp and Oyen wrote a paper detailing the organizational strategy of cross training "flexible workers" ultimately reducing cost, reducing time, increasing quality, and production flexibility via the metric of variety. (Hopp & Oyen, 2004)

Approach

The work that relates to this project falls within three main categories that can be drawn from: Best practice design for Knowledge Management Systems which will be used to modularize training and segments of knowledge itself, Workplace Coaching and the human aspect of knowledge management, and finally the need for the system to contain a mechanism for Continuous Improvement which can be done via provisions in the system for data acquisition and feedback loops that are able to affect the system itself.

Conclusions

The development of a knowledge management system that also fills in gaps for human coaching and feedback will integrate three categories of previously designed systems. In so doing, the benefits of this work will provide a framework that can be used to better integrate knowledge systems into technical manufacturing and maintenance operations.

2. BACKGROUND

Fully integrated and “smart” knowledge management systems, although essential to a properly functioning manufacturing or maintenance operation, is a topic that has not been fully developed in a way that fully integrates all the features and aspects of something that properly fulfills its intended purpose. (Mao, 2021) describes a system utilizing a programmable logic controller “The basic strategic idea of intelligent manufacturing is how to use the rapidly developing IT technology and Internet technology to transform the traditional automated manufacturing model, integrate IT technology and Internet technology into the automatic control PLC system, and change the traditional automated manufacturing model.” A system that makes use of similar technology for increasing workforce capabilities may very well make use of some of the same technologies to fill in the gap for non-automated systems.

Similar designs for Knowledge Management systems such as the one proposed in this paper often revolve around explicit knowledge contained in knowledge repositories, which are often poorly organized silos, nor have they been integrated with the implicit and tacit types of knowledge that can only be obtained by training, coaching, and experiential learning that has been developed on their own but not fully integrated into a smart system and therefore capabilities are not fully realized to their fullest potential. Building a system that does integrate the 3 types of knowledge with a smart system has the potential to contribute benefits to operations.

Such a system would only be complete if it were designed in a way in which the system itself has the capability to continuously improve itself with the aid of data acquisition and human knowledge contributors. This continuous improvement feature is another key aspect of this project.

3. RELATED WORK

The have been past studies and projects in regard to Augmenting Human workforce capabilities with applied technology have been successful to a degree, in fact solutions have been applied in such ways as will be described below. This project combined some proven methods from past projects and knowledge bases to not only fill gaps that had been left but also to introduce novel solutions in some cases by developing and combining existing systems and technologies.

An overall move towards the Smart connected factory, which many call Industry 4.0, is a trend that has a lot of related work, but a large part focused on automation and AI. It incorporates AI, IoT, Data Science, and Automation. The application of the theory has turned out to work exceptionally well in some cases, for instance, how Bright Machines was able to increase yields from 60% to 90% (Bright Machines, 2021). We have also seen several failures in the past. “Automation simply can’t deal with the complexity, inconsistencies, variation and ‘things gone wrong’ that humans can,” and “can create quality problems further down the line,” said Bernstein analysts on a recent automation failure in the Tesla factory (Lopez, 2018). The where the gap falls between what is reasonable and practical to be automated and alternatively where do certain tasks and operations are complex enough to need to be done by humans. By focusing instead on potentials in human skills improvement with the help of already available technology applied in a strategic way, organizations can fill in the gaps described earlier where automation has failed to deliver the desired goals.

Literature Review

Knowledge management systems as a tool for the workforce have been implemented and studied in various ways. (Anzani, 2021) employed a knowledge management system to help marine scientists to be more successful and effective at their work. It employed a combination of both IoT and data acquisition and intelligence systems as well as scientific knowledge and process repository for how to make use of the data and to do the work that was required of the scientists it supported. This is a useful example because although that type of system was used for Scientists, a similar concept should be possible given the level of technical skills and basic understanding that can be leveraged for the common workforce in manufacturing and maintenance. The Pew Research Center found that 85% of Americans own Smartphones and 72% of working age

Americans use social media (Pew Research Center, 2021) and, therefore, it can be accepted that proficient in navigating computer systems to get information and find out the information they are looking for as long as it's applied in an effective manner. It's just not been fully deployed for workforce skills augmentation in a way that impacts production capability improvements.

It really comes down to the way that it's deployed and how good the system is at getting users the right type of information. (Slkar, 2006) describes the role of learning agents, specifically "Autonomous Agents" of a knowledge management system that would be able to provide different levels of assistance and learning capabilities to users.

Integral to such a system to function correctly is the knowledge administrator as described by (Jasimuddin, 2011). The knowledge administrator can be a combination of a human and possibly the system itself in the case of deploying AI here, that the knowledge administrator utilizes. That paper talks about a hybrid knowledge transfer methodology. An artificial intelligence agent can be deployed to assist with the management of the knowledge once the complexity goes beyond a certain threshold.

Projects such as the ones described have shown to have catalytic improvements such as a 14.5% time reduction and a 45.8% quality improvement for those that were capable of using the system while the test subjects that were already struggling had a decrease in capabilities (Korn, 2013).

Workplace Coaching that can be deployed in a timely manner is another key feature to the knowledge management system, and therefore it's essential in the connected factory for the workplace coaching team to relate to the knowledge management system and as well as a paging system and persistent chat app. Applying a uniquely capable human factor to the system adds an important layer of effectiveness. It's been shown that workplace coaching has shown effectiveness based on an overall $\delta = 0.36$ increase in skills affective and individual results (Jones, 2015). The coaching in that study coaching was done both in-person and virtual. As well, innovations to go beyond traditional training by blending technical interfaces and coaching have been proven based on (Grainger, 2001) study. The combination of workplace coaching using a technical subject matter alert network and smart paging system connected to the organization's network as well as having physical locations for skills practice and coaching is a concept that was presented by (Jones, 2003) in a university setting where the students were workplace coaches to the teachers in many ways in order to bridge a generational gap in the use of computer systems.

Continuous Improvement of this system is an integral part of the proper functioning of the knowledge management system itself, and there are innovative ways that the information contained within the system, the information and data that makes available, and in some cases the system itself can be improved. A data feedback mechanism was used by (Strubelt, 2019) where they presented the data on how technicians and machine operators were costing the system by their changing of work sequences. They accomplished this with the help of data acquisition and presented it via simulations.

Along with work sequencing in a production system are the tools and processes required. (Norrie, 1989) designed a method for engineering the manufacturing system by breaking various features of fabrication down into classes, such as in an object-oriented programming language which also included an artificial intelligence aspect. Having a system such as this makes use of several available feedback loops, which also makes it possible to strategically target cross-training plans. (Hopp, 2004) presented a strategy matrix framework as well as tactical frameworks for cross training.

4. APPROACH

Data was collected for this project using peer reviewed literature from the ACM and the City University Library to answer questions about the effectiveness of the system to meet user requirements, the overall design itself, system architecture, implementation details, and technologies used.

The primary users, in this case, are manufacturing and maintenance technicians. In addition, there are secondary users, which also includes management and functional support organizations within an enterprise that will also make use of the knowledge management system to navigate pertinent knowledge and best practices. For measurable effectiveness, the users need to realize improvements in regard to workforce capabilities as increased skills, understanding, and the ability to apply the knowledge that relies on explicit, implicit, and tacit forms. Therefore, the study is addressed by data gathered from sources that support the need for a theoretical design and application of a system that is intended to solve this problem. The

ultimate result being improvements in the quality and performance of the organization, which would be realized through measurable datasets.
Technologies used include agile enterprise cloud systems that integrate with IAAS and custom web applications that utilize curated content housed within standardized content management systems. This is made possible by acquiring the knowledge of the engineering design, industrial planning, policies, processes, and procedures, as well as tribal knowledge that will be converted into institutional knowledge via this system by cataloging, organizing, and retrieving this information.
The technical skills already in place to enable some of the features are addressed quantitatively in a Pew Research Study (Pew Research Center, 2021).
To address the role of explicit knowledge, knowledge repositories are studied along with their potential effectiveness. (Jasimuddin, 2008) conducted interviews in a qualitative manner about such studies.

For the role of implicit and tacit knowledge transfer and experience, the role of a persistently connected Workplace Coaching team fills this role and has been studied including by (Jones, 2015). In that study they used a quantitative data set including 17 studies that met requirements to make it into the study with a total of 2,267 individuals. The project embeds the knowledge and abilities of highly skilled expert technicians as part of the overall knowledge management system.

Agents in human learning were studied (Sklar, 2006) with a formative assessment to test the system itself for operationality and a summative assessment to evaluate how well it is accomplishing its goal. This aspect is about the design of the system and how some parts require a human agent while others can be an electronic or artificial intelligent agent. (Sklar, 2006) also explains the importance of identifying the learners' age and gender to add more context to the ways that data can further be analyzed using the data stratification technique. To build upon that concept, the learner's previous work history, quality, and productivity performance can also be leveraged within the system itself.

Further studies on the overall effectiveness of knowledge management systems and capabilities have been done with "structural equation modeling to test the hypotheses with 302 questionnaires." (Chiu, 2016)

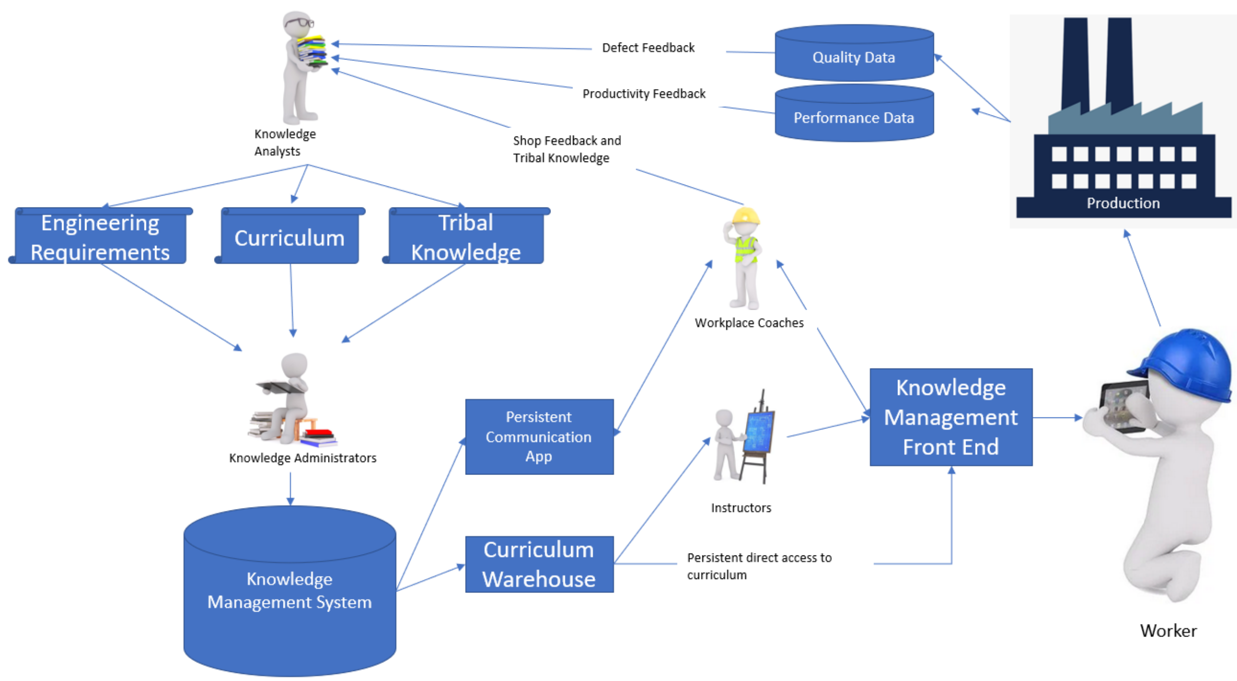

Figure 1

Detailed System Design:

The system presented in this paper focuses on the production or maintenance system worker. As shown in Figure 1 above, the overall Knowledge Management System is a PostgreSQL database hosted in an Enterprise IaaS. All the human interface applications are built upon the Python Django web framework. The tools facing the workforce are for accessing knowledge in the system and communicating with and providing feedback to workplace coaches. There are also data analytic applications used by Knowledge Analysts and Knowledge Administrators.

The Manufacturing and Maintenance workers are first introduced to the Curriculum Warehouse in new hire training when the instructor utilizes the same system as the platform for delivery in the classroom. By doing so, they are also teaching the learners how to navigate the Curriculum Warehouse itself so that when they are out in the shop or the field, they will be able to access all the materials that were used in the classroom should they need a refresher.

The workforce also has a persistent communication application that they can use in order to seek the knowledge of subject matter experts in the form of workplace coaches, to page the Workplace Coaches into the shop floor or field, and they also have the ability to use this application to feed knowledge back into the system by way of the communication mechanism and the Workplace Coaches that also use the system.

The system also contains a continuous improvement imperative to the design as well. Data that is captured from the production environment in the form of Quality and Productivity data is stored in Teradata databases and able to be queried by Knowledge Analysts that are also helped by machine learning capabilities and the use of an application developed directly for the Analysts to develop and maintain knowledge. This knowledge, once developed into the appropriate formats is used to feedback into the engineering department for design improvements, the curriculum department for improvements to the course materials, and directly back into best practice knowledge used in the production environment and maintained by the Workplace Coaches.

Data that has been turned into the various forms of knowledge by the Knowledge Analysts must then be properly catalogued by the Knowledge administrators. Not only are they responsible for cataloguing the knowledge, but also for making improvements to the way the knowledge itself is presented to the end users, therefore they must maintain and make improvements to the front and back ends of the web applications themselves.

5. DATA COLLECTION

Data for this project was collected from academic peer reviewed papers and other sources such as articles and websites. The data collected is then used to demonstrate how combining approaches in the development of a new system can result in improvements outlined within this paper.
Several methods had been used for that data collection based upon the methods outlined within each of the papers themselves.
Results are combined across the disciplines of study to highlight how the combination of techniques for studying the effectiveness of Knowledge Management Systems along with the process and expert networks can hold up to scrutiny regarding the effectiveness of such a system. Key performance indicators include the effectiveness of the proposed knowledge management system, the effectiveness of workplace coaching teams connected to the system, and the effectiveness of process improvement based on feedback from the quality and productivity data when compared with training and targeted coaching efforts.

6. DATA ANALYSIS

The readiness for a modern workforce to have the basic mobile and tablet navigation skills to be able to adapt and excel in the approach presented in this paper is shown evidently in the (Pew, 2011) research study. As shown in Figure 2, 97% of Americans own a cell phone and as shown in Figure 3, 72% use some form of social media. The reason that this study is relevant is because it highlights the level of technological readiness that can be incorporated into technical manufacturing and maintenance roles because an already familiar front-end user interface is already being used widely by people in their personal lives already.

The (Chiu, 2016) Study showed that Knowledge Process Capability is shown to have t value of 3.77 for Organizational Effectiveness and a t value of 2.59 on Organizational Commitment. The visual representation as shown in Figure 4, shows that positive effects of Organizational Commitment on Organizational Effectiveness are supported with the study showing a t value of 3.94.

In addition to the knowledge management and knowledge process capabilities, the processing of knowledge can also be helped by way of workplace coaching, which is essential to fill in the gaps in the knowledge infrastructure system. As shown in Figure 5, the (Jones, 2015) study demonstrated an overall d value 36% increase in workforce capabilities when workplace coaching was successfully implemented. The data collected in this study clearly demonstrates that targeting efforts on Individual-Level Results (d=1.24) with coaches that are Internal-to-the-Org (d=1.40) are shown to be effective measures at increasing overall effectiveness.

Thus, by analyzing this data, the conclusion can be made that the implementation of knowledge management systems embedded with persistent communication mechanisms for subject matter expert networks, and a feedback mechanism for process improvement, when combined in a cohesive system, support the hypothesis presented in this paper and will have a positive effect on workforce capabilities.

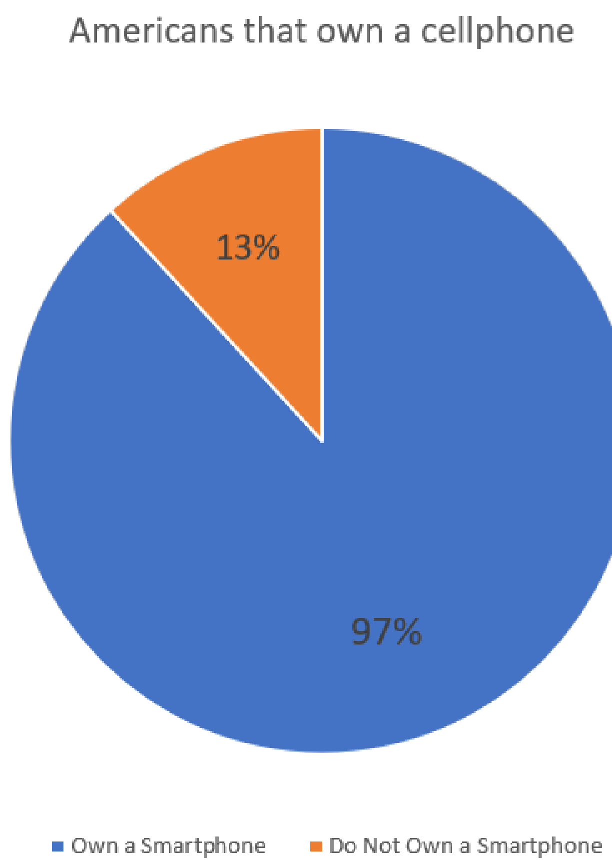

Figure 2

Data Collected by: (Pew, 2011)

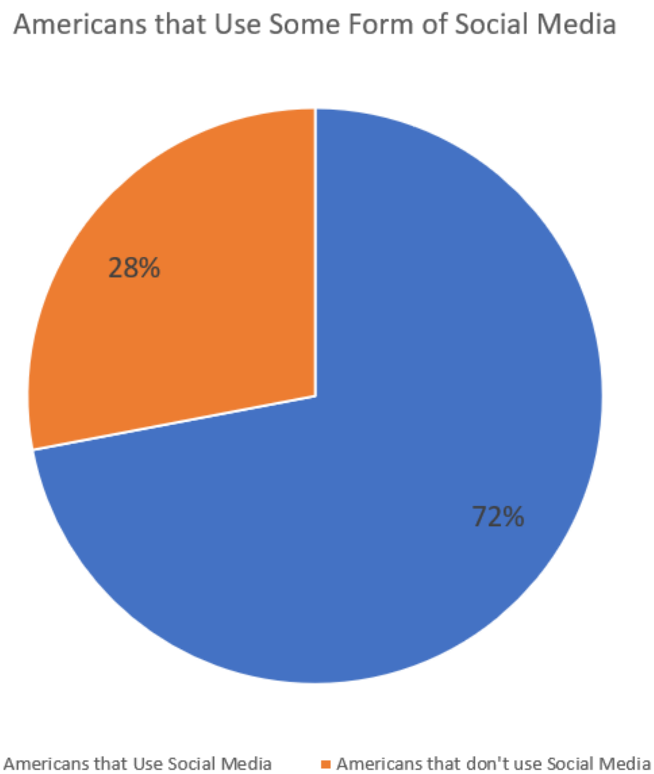

Figure 3
Data Collected by: (Pew, 2011)

Effects of Knowledge Infrastructure / Process Capabilities

H1: KIC has a significant positive effect on organizational effectiveness
H2: KPC has a significant positive effect on organizational effectiveness
H3: KIC has a significant positive effect on organizational commitment
H4: KPC has a significant positive effect on organizational commitment
H5: Organizational commitment has a significant positive effect on organizational effectiveness

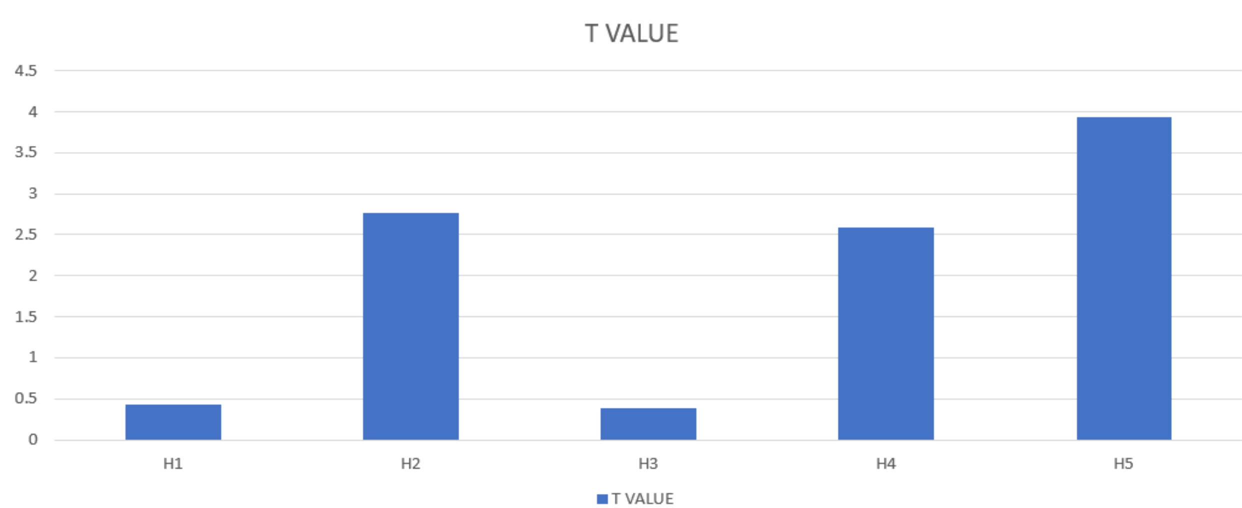

Figure 4
Data Collected by: (Chiu, 2016)

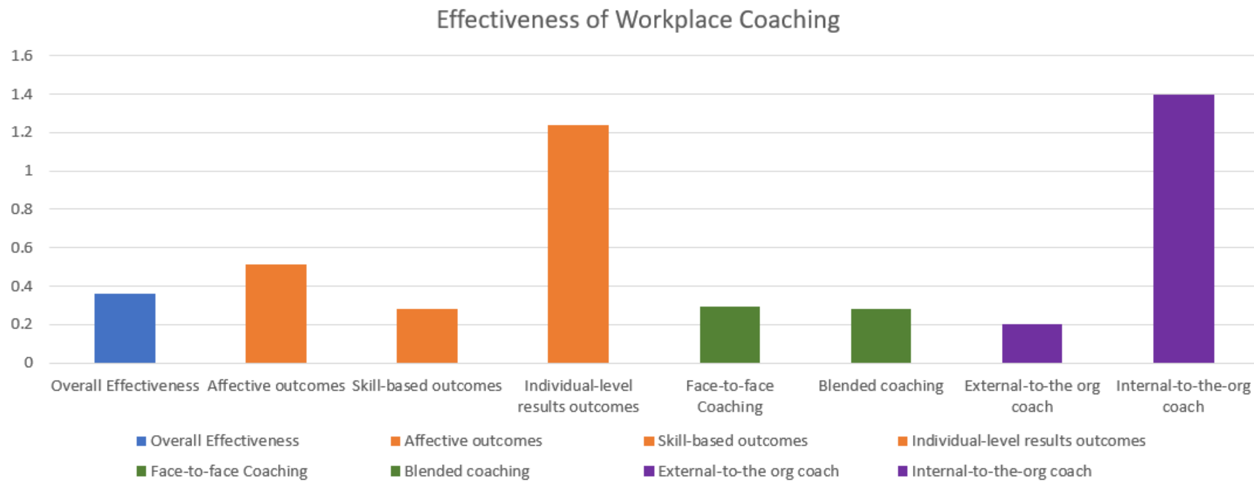

Figure 5

Data Collected by: (Jones, 2015)

7. FINDINGS

The findings for this study are broken down by categories of how different findings based on the data analysis affect how the system works in an efficient way. A number of aspects have been identified including the technological readiness of modern workforce to be able to make use of persistent Knowledge Management System, The type of positive effects that a Knowledge Management System can have and which aspects have the most positive impact, and finally the effectiveness of connected workplace coaching.

Workforce Readiness:
With the overall ownership of cellphones at 97% in America and 72% of Americans using some form of social media, an effective Knowledge Management System that relies on modern mobile responsive design is already mostly enabled from a populous that regularly uses technologies like the ones that the system is built on. The findings presented that this technology is ready to be implemented seamlessly into a production environment since most workers are already quite familiar with navigating similar technologies to communicate and find the answers to knowledge questions.

Knowledge Management System Effectiveness and Types
It has been demonstrated that the biggest impact per type of Knowledge Management System equates to ones that focus on Knowledge Process Capabilities (t=3.77). This, in turn, also has a sizable positive impact on Organizational Commitment (t=2.59). Organizational Commitment has been demonstrated to have a direct effect on overall Organizational Effectiveness (t=3.94). Therefore, findings here show that successfully implemented Knowledge Management Systems targeted specifically at Knowledge Process Capabilities and Organizational Commitment are the most impactful ways to design such a system for the highest impact.

Workplace Coaching Effectiveness and Type
Workplace Coaching, when properly integrated, has been shown to create a 36% increase in overall workforce capabilities and therefore supports the hypothesis that it is a worthwhile endeavor to make use of such a practice in an overall Knowledge Management System. Different types and outcomes were studied. The ones that show the greatest benefits were focused on Individual-level results (d=1.24), and the best individuals suited to the role of Workplace Coaches were hired internally to the organization (d=1.40).

8. CONCLUSION

The way to increase workforce capabilities through knowledge sharing is best implemented with the use of technology built upon planned systems that include enterprise cloud Knowledge Management Systems, empower persistently connected Workplace Coaches using this system, and plan in feedback loops to drive improvements into the overall system.

Limitations:
This project was constrained by time for design and implementation as well as a lack of studies that prove the overall effectiveness of this research. The various objectives were analyzed on their own and then combined to demonstrate how overall effectiveness can be increased by utilizing best practices as shown through previous research.

Recommendations:
As a direct result of this research, organizations are encouraged to begin investing in the three-tiered approach as shown in the objectives that have been studied here. The high-level system design presented in this paper may not be achievable within a short time, but sustainable gains can be made by investing in smaller deliverables such as knowledge management systems that fall within a specific targeted scope, workplace coaching in the form of a dedicated team or as a motivating side-responsibility of team members or implementing a system for assessing and improving the overall process for knowledge management and skills development.

9. FUTURE WORK

A highly effective Knowledge Management System will depend on closely analyzing the implementation of the system design presented in this paper. Future work involves implementing tiered levels of improvement into production systems in targeted ways that would benefit the environment. Upon introduction, the data analysis section of this design has a reflective aspect built into the scheme and should therefore be implemented in such a way that opportunities are found in each round, implemented, and further analyzed.

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