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Implementation of Actionable Gamification Design Framework in Machining Training

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Abstract

With the widespread adoption of Industry 4.0 standards and technologies in machining, the machining processes have become increasingly more machine-centered, "*smart*", and automated. However, contrary to popular expectations, this total automation approach has not amended the issue of labor shortages in the machining industry, and the workforce demand gap has been gradually expanding in recent years. Although the workforce shortage issue is a complicated and multidimensional problem, it can be seen that one of its underlying causes is the conventional approach to training prospective employees in the industry. Unfortunately, evaluation of outdated training methods, along with discussing possibilities for their improvement, have not yet attracted sufficient attention.

In order to effectively accomplish training goals, instructor-led and hands-on training methods are widely adopted in most machining training programs. However, the aspect of trainee engagement, interest and involvement is often ignored, which can be one of the main reasons for dropping enrollment and retention rates observed in many machining related programs in trade schools and community colleges. To spark the interest of the younger generation in this career field, more attention should be paid to incorporating training methods that are attractive to young students. Interactive training programs with game-derived elements are potentially a good solution to address the shortcomings of current training methods.

Gamification, which is a technique of facilitating training and learning procedures by incorporating game-like elements, has the potential to enhance student interest and engagement. In such a gamified application, game design elements and gameplay mechanics are added to motivate trainees to stay engaged when performing often repetitive and mundane machine tool operations. It can also help with mitigating the mental fatigue trainees and workers might experience due to lack of interest and professional burnout syndromes observed in machining environments. Gamification is a promising approach to improving self-motivation by stimulating the desire of pursuing gaming-inspired goals (such as for example earning a level-up badge or attaining certain rewards). By connecting the training tasks and outcomes to a gaming goal, trainees would be more likely to derive actual enjoyment from the training procedures and feel less like they are being forced to perform certain tasks and activities.

The objective of the proposed study is to devise a surveying method to systematically evaluate the conventional machining workforce development procedures by applying the Octalysis gamification design framework, comprising eight core drives of gamification and their corresponding scores. The outcome of this study is the proposal of a new perspective of evaluating the current machining training methods in the aspect of student attraction and engagement and exploring possibilities to improve them with appropriate game-like elements.

1. Introduction

The modern machining industry remains one of the vital sections of the world economy, with a substantial workforce - in the USA alone, the machining industry has employed over 300,000 skilled machine tool operators, as of 2021 [1]. The issue of an aging and declining machinist workforce is brought up by industry sources, with an average age of trained professionals in the field reported at approximately 45 to 56 years [2, 3]. The shrinking workforce causes a need to devise methods to ensure increased enrollment and retention of trained machinists to meet future industrial demands. If researchers and the industry fail to properly understand the negative impact of declining enrollment and a shrinking, aging workforce, it is expected to have a strongly negative impact on the future development of the machining industry [4].

Addressing the aforementioned issues related to an aging and shrinking machinist workforce necessitates devising new methods and approaches to attract the younger generation of prospective professionals to the industry and to retain them as long-term workforce. Currently, instructor-led and hands-on practical training methods are employed in machining workforce development programs. However, the aspect of student motivation, involvement and satisfaction is often ignored, which is one of key potential reasons for dropping enrollment and retention rates. To attract the younger generation to machining industry careers, more attention needs to be paid to incorporating novel training methods that are more appealing and engaging to younger students. Interactive training programs with game-like elements (gamified training programs) are potentially a viable solution to effectively addressing the shortcomings of traditional training methods.

The process of gamification, defined as implementation of game-specific mechanics and dynamics in non-gaming applications [5] has been of interest in machining-related applications, including workforce development. As video games are designed with the goal of providing enjoyment to the user, potential benefits of gamification include enhanced user engagement, motivation and work satisfaction, helping mitigate workforce attrition and professional burnout. Several examples of process gamification applications related to the machining industry can be found in open literature. A simplistic virtual machine tool model capable of realizing the basic functionalities of real CNC machine tools was shown in [6]. A gamified application that aids the workers in assembly tasks and adapts to their skill level, while also using an achievement and a leaderboard system was presented in [7]. A gamified augmented reality (AR) based approach was showcased in [8] in an assembly line environment to increase worker productivity, product quality and improve workplace ergonomics. An expert system that tracks operator progress in maintenance operations and displays adaptable skill level based instructions and tips was proposed and presented in [9]. A smartphone based application for gamifying CNC operator jobs was developed in [10]. Here, a mission-based system where operators select certain tasks to perform and compete to achieve shortest production time and total yield of non-defective parts was proposed. Field testing of the app showed a positive impact on job motivation and worker satisfaction during tests in industrial environments. Overall, selecting machining industry relevant examples of gamification systems presented in open literature can be deemed relatively simple, and there is significant room for further development in terms of available features, complexity and variety, which are of particular importance in provoking and sustaining user engagement [11].

Noted examples from open literature show that gamification is a potentially promising approach for improving the interest, job satisfaction and self-motivation of workers and trainees by connecting training or work tasks to gaming goals. Due to the complex nature of gamification, comprehensive design frameworks, such as *Octalysis*, are proposed [12]. They evaluate multiple aspects of the process in the aspect of factors that make successful video games and mobile applications engaging to the user and aim to provide a robust basis for gamification.

The main objective of this study is to provide an overview of the *Octalysis* design framework from a machining workforce development standpoint. This is to provide a basis for future efforts to systematically evaluate the machining workforce development programs by applying the *Octalysis* design framework for their improvement and gamification.

2. Octalysis gamification design framework in machining workforce development and education

Octalysis is a design framework proposed by Yu-Kai Chou in his book *Actionable Gamification: Beyond Points, Badges, and Leaderboards* [12]. As stated by Chou, games and applications create and sustain interest because they are capable of efficiently motivating the player towards certain activities. It is also noted that the game developers have devoted decades to mastering this goal. This is a strong argument for the use of gamification to enhance the user experience in non-gaming activities. To evaluate the various aspects that make a game, activity or an application engaging and interesting, Chou proposes the use of his standardized framework comprised of eight aspects, called Core Drives. Those so-called Core Drives are thus defined as follows, according to [12]:

1) *Epic Meaning and Calling*: this Core Drive is described as the factors making the user believe that they are doing something of particular importance. A successful accomplishment of this Core Drive is associated with the user devoting a substantial amount of their time and effort towards a particular task, even when it is not associated with obtaining any particular extrinsic rewards.

2) *Development and Accomplishment*: it is correlated with the desire to make progress, develop, and master new skills and problem-solving abilities. Here, an important observation is made in [12]. An actual sense of challenge needs to be created to lend legitimacy to badge, trophy and reward systems. If not associated with specific

challenges beforehand, those gamification tools will fail to evoke a sense of accomplishment and development.

3) *Empowerment of Creativity and Feedback*: this aspect of *Octalysis* pertains to situations where the users are engaged in a creative process and are given freedom to repeatedly overcome obstacles. It is paramount that the users are not only given freedom to be creative, but that they can also see the results of their work, receive feedback and be allowed to modify their strategy to obtain better results. Appropriate integration of mechanics associated with this Core Drive ideally results in a scenario in which the designer does not need to periodically introduce new content, as the users will remain engaged out of their own volition.

4) *Ownership and Possession*: the fourth Core Drive is related to user motivation and satisfaction stemming from a sense of controlling a certain aspect of the process and the desire to accumulate wealth, be it physical or virtual. There are two aspects to this. Firstly, it is related to customizability - for example, users altering the appearance of video game avatars feel a sense of ownership towards the game environment. Secondly, providing the user with a degree of control over a project, process or the organization is a good example of accomplishing this Core Drive.

5) *Social Influence and Relatedness*: this aspect of the *Octalysi*s framework concerns the social elements that motivate the users, such as social acceptance, feedback, companionship, mentorship, envy, and competition. An example situation evoking this Core Drive is when an individual observes a co-worker or a teacher that possesses great proficiency at a particular task, making the observer motivated to attain the same skill level.

6) *Scarcity and Impatience*: associated with rarity or exclusivity, this Core Drive embodies a sense of desiring something due to it being difficult or time consuming to obtain. When the user cannot obtain the thing they want immediately, they will think about it and return to the product/platform given the first chance to do so.

7) *Unpredictability and Curiosity*: this Core Drive is associated with scenarios involving unpredictability, when the users are uncertain what will happen next. This enhances user engagement and heightened awareness. The mechanics of this Core Drive are related to human responses to situations outside of regular pattern recognition cycles and routines.

8) *Loss and Avoidance:* associated with the motivation to avoid losing the results of one’s previous work and avoiding negative consequences of certain actions or inaction. This Core Drive can be utilized to keep the users engaged and motivated to use the product. It is associated with limited time windows for task completion and occasional availability or certain activities.

A graphical representation of the eight Core Drives of the *Octalysis* design framework and their categorization in terms of motivation types is shown in Fig. 1.

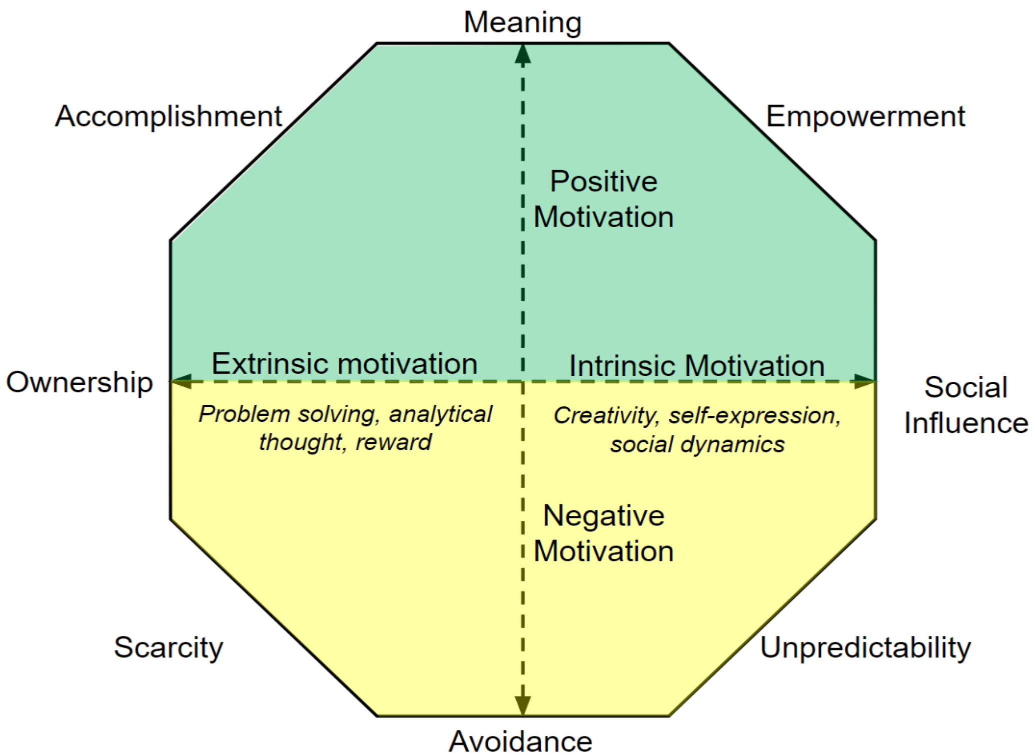

Fig. 1. The Octalysis gamification framework

As seen in Fig. 1, the eight Core Drives of the *Octalysis* framework are grouped by the nature of user motivation. The Drives corresponding to intrinsic motivation, which are associated with creativity, self-expression and social interaction are organized on the right side of the octagonal graph. Drives related to analytical thinking, problem solving, and extrinsic rewards/gratification are grouped on the left. The characteristics are also grouped by the positive or negative nature of user motivation. Drives that thrive on motivating the user to get creative, refine their skills and bring about a sense of accomplishment and meaning are placed in the upper half of the octagon. On the opposite spectrum, Drives tied to feelings of loss, scarcity and uncertainty are placed in the bottom half of the figure.

A literature review reveals prior successful applications of the *Octalysis* gamification framework to evaluate and improve existing educational programs and environments. Interactive story-driven teaching methods aided by the use of electronic teaching aids were shown to enhance student learning outcomes in a primary school English language class setting [13]. A comparison study was conducted in [14], where the authors have compared learning outcomes for traditional and gamified e-learning platforms for a programming class. The authors have found that students who used a gamified platform received higher grades and expressed higher motivation and engagement in surveys when compared to their peers who used a traditional e-learning course. A comparison of select gamified platforms and applications has shown that the most successful solutions rely heavily on positive motivation and balancing intrinsic motivation with prospects of extrinsic rewards [15]. A similar focus on positively and intrinsically motivating factors was found in [16], where the authors have evaluated a gamified crowdsourcing website [17]. Teaching effectiveness of an e-learning platform was evaluated using the *Octalysis* gamification framework in [18]. The authors have formulated a set of survey questions corresponding to eight Core Drives of the framework and used the results as a benchmark for future gamification efforts, showing key areas for improvement and shortcomings that need to be addressed to improve learning outcomes. Unlike other studies [15, 16] the authors of [18] have surveyed actual platform users, avoiding author bias during evaluation of gamification outcomes, where scoring criteria were not provided, and the evaluation was conducted arbitrarily by the authors.

3. Octalysis evaluation of existing machining workforce development programs and educational settings

The first necessary step in evaluation of current machining workforce development programs is formulating a set of questions that are closely tied to each aspect of the *Octalysis* design framework. To avoid researcher bias and arbitrary assignment of Core Drive scores, surveying of actual trainees and students is intended as means of training program benchmarking. To achieve this goal, eight survey questions, each pertaining specifically to a particular Core Drive, were prepared. For maximum clarity, questions were formulated in a concise manner, with as little room for ambiguity as possible. Moreover, additional remarks were used whenever deemed necessary to explain certain concepts and terminology used in select survey questions. Consequently, the resulting survey questions and remarks are as follows:

<u>Question #1 (Core Drive 1 - Epic Meaning and Calling)</u>: The program made me realize the importance of its successful completion and provided me with appropriate information regarding my future career prospects and relevance of my future work.

Remarks for Question #1:

"Relevance of future work" refers to the following: 1. Explanation of why the industry needs trained machinists; 2. What is the current job market situation in terms of the demand-supply gap for trained machinists; 3. How will future machinists and engineers working in the machining sector contribute to the development of the local/national economy.

The term *"Career prospects"* refers to the following: 1. Income ranges for newly trained machinists; 2. Possibilities of career advancement in terms of pay increases and advancement to higher positions; 3. Anticipated growth of the machining industry locally and nationally.

Question #2 (Core Drive 2 - Development and Accomplishment): The training program has allowed me to obtain and develop new skills and forced me to apply them to overcome challenges, engaging me in problem solving activities.

Question #3 (Core Drive 3 - Empowerment of Creativity and Feedback): The training program has allowed me to use my creativity to solve problems and challenges presented to me. I received feedback regarding my approach and was allowed to alter it to obtain improved results.

Question #4 (Core Drive 4 - Ownership and Possession): The hands-on portions of this training program have allowed me to customize and personalize my projects and gave me a sense of ownership over assigned tasks and projects.

Remark for Question #4: Here, a good example of freedom to customize and personalize is the approach taken towards projects / hands-on activities. Let us consider a case in which the students learn about milling and drilling operations and are then subsequently expected to perform those operations on an actual machine. If they are allowed to design their own part or modify the part design given to them on a technical drawing, the sense of ownership/customizability is successfully evoked. If the students are given a technical drawing of the part and are not allowed to alter it in any manner, there is no room for personalization/customization and the training programs fall short in this aspect.

Question #5 (Core Drive 5 - Social Influence and Relatedness): The training program encouraged me to collaborate and compete with my fellow students by encouraging teamwork and introducing competitive activities.

Question #6 (Core Drive 6 - Scarcity and Impatience): I was presented with opportunities of obtaining extra credit by participating in non-mandatory tasks, such as timed quizzes and optional homework / in-class activities.

Remark for Question #6: For clarity's sake, the question pertains to basic extra activities. Another element associated with the Scarcity and Impatience drive is the rarity/exclusivity factor. A good example of this would be extra certification of being awarded a top student/trainee status for completion of certain tasks, such as extra homework, in-class project activities or participation in a non-mandatory portion of the course that grants additional certification upon completion.

Question #7 (Core Drive 7 - Unpredictability and Curiosity): The course contained elements of randomness and has kept me curious and demanded me to maintain heightened awareness.

Remark for Question #7: Here "*elements of randomness*" can pertain to events such as previously unannounced in-class activities (for example short calculational exercises for computing tolerances etc.) and the random nature of hands-on portions of the class. For example, different student groups would operate various machine tools during different class sessions to accomplish various project activities (given theoretical foundations and instructor demonstrations on how to properly operate them beforehand). Random assignments have been found to enhance student motivation and satisfaction in previous learning environment gamification efforts [18].

Question #8 (Core Drive 8 - Loss and Avoidance): I was properly motivated to track my progress to maintain my performance in the course and to avoid losing the results of my prior work.

Remark for Question #8: Here, a good example of encouraging students to maintain performance in the course is the inclusion of an anonymized scoreboard on the e-learning platform associated with the course. Moreover, extra credit can be granted to top students as a motivating factor. Clear grading criteria with previews of course performance and grade weights can also serve to motivate students to keep up their performance in the course to avoid receiving a lower grade when they perform poorly on homework/project assignments.

4. Case Study

To showcase the proposed approach, the presented survey questions were prepared in the form of a sheet. One graduate master's student from the Rochester Institute of Technology (RIT) student population enrolled in the Mechanical Engineering major was asked to complete the survey. The survey pertained to the course named *MECE-104 Engineering Design Tools* offered at RIT Kate Gleason College of Engineering. The evaluated class consisted of mixed instruction, comprised of laboratory sections focusing on the use of CAD software to design machine components and hands-on sessions teaching the use of conventional machine tools to fabricate said parts [19]. Course synopsis and learning objectives are presented in Table 1.

Table 1. Details concerning the course subject to student evaluation [19]

Course name and code
Engineering Design Tools MECE-104
Synopsis
This course combines the elements of Design process, Computer Aided Design (CAD), and Machine Shop Fabrication in the context of a design/build/test project.
Learning objectives
• Learn to work in a team setting • Use a formalized design process to make rational design choices • Use a CAD software package to create three-dimensional models and assemblies • Safely fabricate metal parts using vertical mills and lathes

The student was asked to respond to each survey question from Section 3. of this work with a rating of 0-10, where 0 meant strong disagreement with the posed statement and 10 meant strong agreement. Before completing the survey, the student was asked to carefully read each statement and supplementary comments for questions that included them (questions 1, 3, 6, 7 and 8). Results are presented in Table 2.

Table 2. Student responses to survey questions

Question #	1	2	3	4	5	6	7	8
Core Drive	Epic Meaning	Accompli shment	Empowe rment	Ownersh ip	Social Influence	Scarcity	Unpredic tability	Loss
Scoring	10	10	4	4	4	4	4	10

Subsequently, obtained results were used to construct an *Octalysis* octagon graph with the use of the free online Octalysis tool [20]. The graphical representation of scores that the considered course obtained in the Octalysis evaluation is shown in Fig. 2.

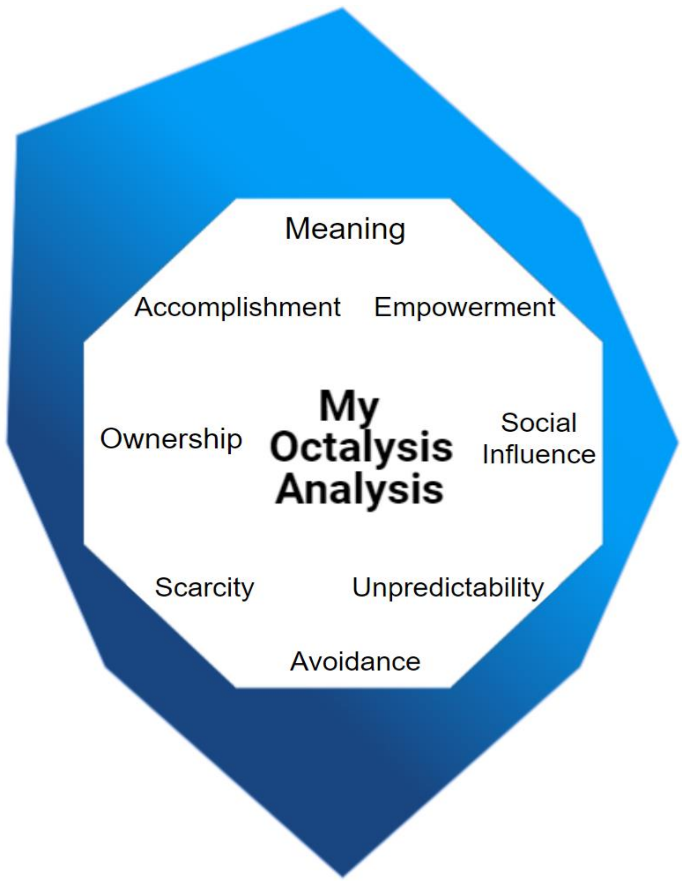

Fig. 2. A graphical representation of the *Octalysis* evaluation for the MECE-104 course [20]

Analysis of the results presented in Table 2. And Fig. 2. allows to infer that the evaluated educational program has scored highly in Core Drives 1, 2 and 8, where the student has decided to assign the highest score when responding to survey questions.

In the context of Core Drive 1, this means that from a student perspective, the course material made them aware of the importance of taught material and has provided them with appropriate information regarding both the relevance of machining education and future career prospects that can be available after its successful completion.

High scoring on Core Drive 2 can be attributed to the nature of the class, which is constructed as a semester-long design/build/test project. This effectively means that the students are required to develop new skills, in this case concerning both CAD software operation and machine part design, as well as practical and motor-based skills required to operate the machine tools. Effective fabrication of the designed part will inevitably pose challenges to inexperienced machinists, and they will be required to go through multiple iterations of the fabrication process to obtain a part of desired quality.

The MECE-104 course uses an e-learning platform that allows students to keep track of their grades and preview their final grade based on their performance to date. The platform displays notifications and prompts every time a new grade is received. In addition, it informs the students when new assignments and reading materials are posted by the instructor. Highest score assigned to Core Drive 8 signifies that this e-learning platform is effective in keeping students motivated to track their progress in the course and helping them understand that they need to keep performing well in class in order to not lose the results of their prior work.

The evaluated course was assigned a below average rating of 4 on Core Drives 3, 4, 5, 6 and 7. This allows to identify the weaknesses and shortcomings of the program and propose example ideas for its improvement. Here, it is noteworthy that successful gamification is not synonymous with scoring highly on all Core Drives [12] and that best practices often focus on balancing intrinsic and extrinsic motivation, with predominant use of mechanics and Core Drives associated with positive motivation [15]. Hence, the target should be to obtain an observable improvement in select Core Drives that scored low and not to score high in all aspects of the *Octalysis* framework.

Low scoring on Core Drives 3 and 4 has several implications. Firstly, it hints that the student did not feel empowered to use their creativity to overcome posed challenges. Instead, they were expected to strictly follow a set of rules and procedures taught in the class to obtain a satisfactory outcome. Cutting parameter values, tools, stock dimensions were preassigned, and the students were required to follow a specific order of cutting operations. Second of all, the course did not elicit a feeling of ownership and was lacking in the aspect of customizability - students were assigned parts that they were required to draw in CAD software and machine later, with no room for alterations and redesign. Here, possibilities for improvement comprise several potential alterations to the curriculum and the teaching method. Allowing students a greater degree of freedom by letting them design custom parts by choosing from a set of available stock dimensions and predefined features (such as holes, pockets, chamfers etc.) would stimulate their creativity and let them feel a sense of ownership over the project. At the same time, it would ensure that parts are feasible (by limiting stock dimensions) and that all students will acquire skills required for the same operations (by imposing necessary part features). Letting students choose from several available tooling options, allowing them to adjust cutting parameters within a predefined range and choosing the order of operations to fabricate the parts would allow them to use their creativity. At the same time, constraining the choices to a few rational alternatives and teacher approval of part designs, tooling choices, and cutting parameters would prevent students from feeling overwhelmed or uncertain about failing/underperforming.

A below average score was also assigned to Core Drive 5, relating to social/teamwork aspects of the course. As the student reported, the program is designed as an individual project. Students were not required or allowed to cooperate with their teammates during the CAD drawing and fabrication stages. It should also be noted that this approach is in opposition to one of the stated learning goals, which is working in a team setting. Such an approach also does not allow students to develop soft skills related to teamwork and rids the course of the competitive aspect. Potential improvements include arranging students to work in small groups of 2-3 people to develop a cutting strategy, letting each student machine the part separately and then requiring them to compare results in terms of product quality (measured vs. nominal dimensions) and/or productivity (total cutting time). The e-learning platform used in the course does not contain leaderboards, possibly because of anonymity concerns. A solution that could be explored is a feature that shows the students how well they performed in relation to their peers by displaying their position on an anonymous leaderboard.

Core Drives 6 and 7, related to scarcity and unpredictability, also received a below average grade from the student. The course followed a predefined syllabus and did not contain any unannounced elements or activities that could be completed to earn extra credit. While Core Drives 6 and 7 help maintain user awareness and engagement, they are related to negative motivation and can make course takers uncomfortable or anxious. Moreover, it was previously found that negative motivators are associated with short-term engagement [15], which is not an ideal tool for sustaining student motivation and interest for a semester-long project.

5. Summary and Conclusions

The presented work concerns the application of the *Octalysis* gamification design framework for gamification and improvement of existing machining workforce development. A particular emphasis was placed on translating the *Octalysis* framework and its eight Core Drives to future applications in gamification and refinement of machining workforce development programs. The first step to achieving this goal is surveying of trainees and students to obtain insight concerning key areas for gamification of the learning process, along with understanding key shortcomings of extant training programs that need to be addressed. With this in mind, a set of survey questions was prepared, where each question pertained specifically to a particular *Octalysis* Core Drive. Aside from translating the discussed framework into a machining workforce development appropriate context, evaluation of previous applications of the Octalysis framework was conducted. Additionally, a student who participated in a machining course at RIT was surveyed to showcase the proposed method and obtain preliminary feedback regarding the evaluated training program. Aside from this paper's area of focus, a broader scope of activities is necessary to achieve the goal of the proposed research project, as summarized graphically in Fig. 3. Stages marked in green constitute the focus of research efforts associated with this paper, with other necessary future research activities marked in gray.

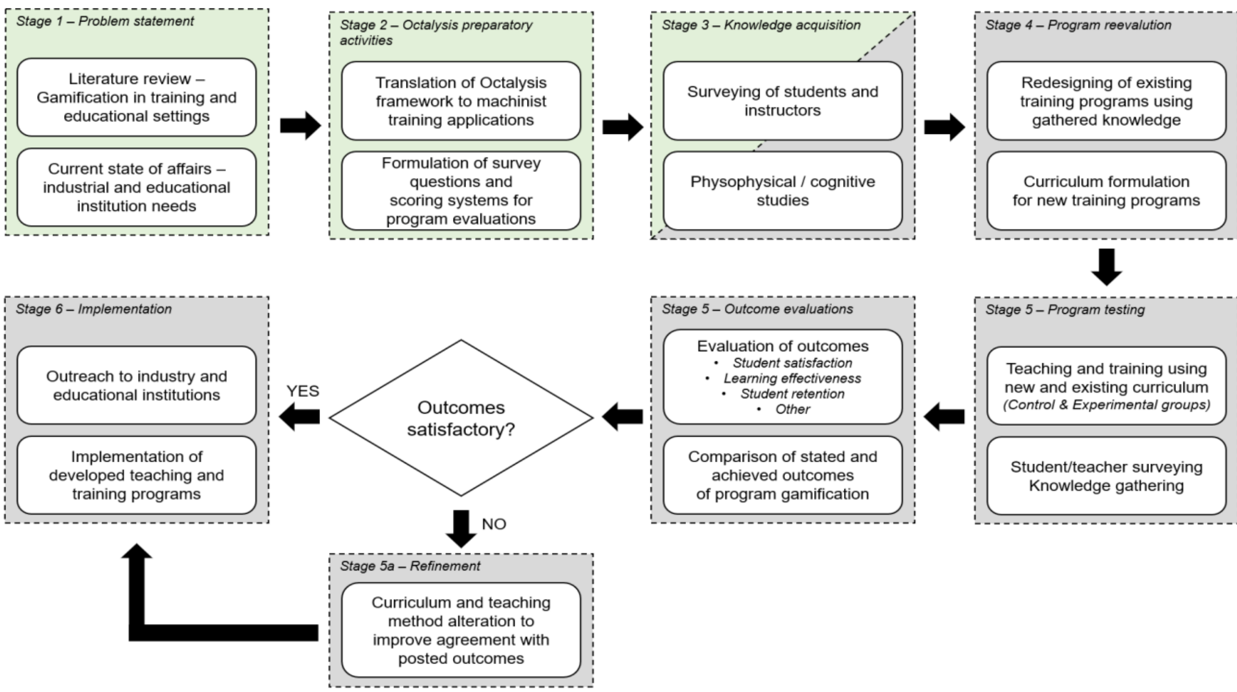

Fig. 3. A graphical representation of proposed research activities for machining workforce training program gamification

The main takeaways from presented work are as follows:

- Gamification of workforce development programs is a promising solution to addressing the current situation of shrinking machinist workforce, by improving enrollment and retention of prospective professional machinists to meet industrial demands.
- Select research works from open literature show that gamification in the educational sector is a viable tool for improving learning outcomes, student performance, satisfaction, and motivation.

- Outcomes of teaching program gamification can be evaluated by obtaining comparative measures of student satisfaction, motivation and teaching outcomes when comparing the results of teaching with the use of gamified and traditional teaching methods and curriculums.
- Student surveying is a viable technique for evaluating training courses with the use of the *Octalysis* framework, helping to understand student needs and help in effective gamification of teaching programs by identifying areas for improvement.
- Arbitrary scoring criteria and program evaluation methods are a potential source of ambiguity, which can negatively affect the credibility of subsequent gamification framework applications and the quality of outcomes. To avoid this, survey techniques based on relevant, concise questionnaires need to be employed in training program evaluation to obtain appropriate insights of actual substance to future program teaching gamification.

For future work, student surveying of a larger sample group by utilizing the methodology proposed in this work is planned. Actual feedback from a student group will be used to determine the weaknesses and potential areas for improvement for the evaluated courses, aiding in determining the key Core Drives of concern for subsequent teaching program gamification. After the surveying procedure is concluded and student feedback is gathered, a selection of context-appropriate gamification mechanics and elements needs to be performed for subsequent training program gamification. In addition to survey outcomes, results from pending cognitive studies, are to be used in gamification and improvement of existing workforce development programs. Additional work concerning categorization of knowledge types and learning outcomes is planned to refine the teaching methods and devise metrics for course evaluation. Ultimately, comparative testing of gamified and traditional teaching programs is planned to obtain measurable results concerning the effect of program gamification on select metrics, including student performance, retention, motivation, and satisfaction.

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References

[1] “Machinists,” *U.S. Bureau of Labor Statistics*, 31-Mar-2022. [Online]. Available: https://www.bls.gov/oes/current/oes514041.htm. [Accessed: 24-Apr-2023].

[2] J. Toney, “Where have all the machinists gone?,” *Humanix*, 01-May-2020. [Online]. Available: https://humanix.com/where-have-all-the-machinists-gone. [Accessed: 24-Apr-2023].

[3]Kari, “Bye-Bye Boomers: What retiring Machinists mean to plant safety,” *Rockford Systems, LLC*, 06-Apr-2023. [Online]. Available: https://rockfordsystems.com/bye-bye-boomers-what-retiring-machinists-mean-to-plant-safety/. [Accessed: 24-Apr-2023].

[4] C. Varianou-Mikellidou, G. Boustras, O. Nicolaidou, C. Dimopoulos, and N. Mikellides, “Measuring performance within the ageing workforce,” *Safety Science*, vol. 140, p. 105286, 2021.

[5] S. Deterding, M. Sicart, L. Nacke, K. O'Hara, and D. Dixon, “Gamification. using game-design elements in non-gaming contexts,” *CHI '11 Extended Abstracts on Human Factors in Computing Systems*, 2011.

[6] dos Reis Albano, M. V., de Araújo Junior, L. O., Bhering, F. P., & Gerais, M. Virtual 3D Learning Environment: Development of Virtual Objects and Curricular Units for CNC. *Alive Engineering Education*, 111.

[7] J. Ulmer, S. Braun, C.-T. Cheng, S. Dowey, and J. Wollert, “Human-centered Gamification Framework for manufacturing systems,” *Procedia CIRP*, vol. 93, pp. 670–675, 2020.

[8] O. Korn, P. Muschick, and A. Schmidt, “Gamification of production? A study on the acceptance of gamified work processes in the automotive industry,” *Advances in Intelligent Systems and Computing*, pp. 433–445, 2016.

[9] N. Nikolakis, G. Siaterlis, and K. Alexopoulos, “A machine learning approach for improved shop-floor operator support using a two-level collaborative filtering and gamification features,” *Procedia CIRP*, vol. 93, pp. 455–460, 2020.

[10] M. Liu, Y. Huang, and D. Zhang, “Gamification's impact on manufacturing: Enhancing Job Motivation, satisfaction and operational performance with smartphone-based gamified job design,” *Human Factors and Ergonomics in Manufacturing & Service Industries*, vol. 28, no. 1, pp. 38–51, 2017.

[11] G. Zichermann and C. Cunningham, .”Gamification by design: Implementing game mechanics in web and mobile apps.”, O'Reilly Media, Inc., 2011.

[12] Y.-K. Chou, *Actionable gamification: Beyond Points, badges, and leaderboards*. Fremont: Octalysis Media, 2019.

[13] S. Oliveira and M. Cruz, “Gamifying the Story or Storifying the Game?-Chou’s (2016) Octalysis Framework in English Learning at Primary Schools,” *Proceedings of Play2Learn*, pp.351, 2018.

[14] F. A. Pratama, R. M. Silitonga, and Y.-T. Jou, “Rimigs: The impact of gamification on students’ motivation and performance in programming class,” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 24, no. 3, p. 1789, 2021.

[15] T. Ouariachi, C.-Y. Li, and W. J. Elving, “Gamification approaches for education and engagement on Pro-Environmental Behaviors: Searching for best practices,” *Sustainability*, vol. 12, no. 11, p. 4565, 2020.

[16] V. Yfantis and D. Tseles, D, “Exploring Gamification In The Public Sector Through The Octalysis Conceptual Model,” *Era-12 International Scientific Conference*, 2017.

[17] “Challenge.gov,” *Challenge.Gov*. [Online]. Available: https://www.challenge.gov/. [Accessed: 24-Apr-2023].

[18] F. Marisa, S. Sakinah, Z. Izzah, A. L, R. David, and A. Aris, “Evaluation of student core drives on e-learning during the covid-19 with octalysis gamification framework,” *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 11, 2020.

[19] “Mechanical Engineering BS - Curriculum,” *RIT*. [Online]. Available: https://www.rit.edu/study/curriculum/9efe4957-73b9-42c9-830e-a85a7d2bc7e6. [Accessed: 24-Apr-2023].

[20] “Octalysis tool,” *Learn Gamification with Yu-kai Chou: cheat codes to win the game of life*. [Online]. Available: https://yukaichou.com/octalysis-tool/. [Accessed: 24-Apr-2023].