A Framework for Motivating Sketching Practice with Sketch-based Gameplay

Blake Williford
Sketch Recognition Lab
Texas A&M University
bwilliford@gmail.com

Matthew Runyon
Sketch Recognition Lab
Texas A&M University
matrunyon@tamu.edu

Josh Cherian
Sketch Recognition Lab
Texas A&M University
jcherian14@tamu.edu

Wayne Li
College of Design
Georgia Tech
wayne.li@design.gatech.edu

Julie Linsey
iDREEM Lab
Georgia Tech
julie.linsey@me.gatech.edu

Tracy Hammond
Sketch Recognition Lab
Texas A&M University
hammond@tamu.edu

ABSTRACT

Sketching is a valuable skill to learn but requires extensive motivation and practice to improve. We present a framework for motivating practice with sketch-based gameplay that is rooted in a grounded theory study of the motivations of various individuals with different skills levels. The individuals interviewed included a range from novice and intermediate industrial design students to established design professionals. Four categories emerged that explain the differences in motivation between individuals with different skill levels, including achievement, competition, communication, and creativity. We also present a case study of the implementation of two different gameplay approaches for encouraging line work practice in a high school art course and a university sketching course. The study revealed that both approaches were very engaging and motivating to students, with 72,842 lines practiced across the 150 students overall. We also gained insights about how the approaches differed in motivating students, and share principles we learned on motivating students with gameplay that may be useful to other researchers, educators, and technologists.

Author Keywords

Sketching; Drawing; Art Education; Design Education; Gameplay; HCI; Human-computer Interaction; Games; Serious games; Game-based Learning; Gamification; Motivation

CCS Concepts

•Human-centered computing → Interactive systems and tools; Interaction techniques; •Applied computing → Computer-assisted instruction;

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Figure 1. Sketch-based gameplay can help motivate practice of sketching fundamentals. We developed a theoretical framework for motivating individuals of varying skill levels, and explored two different gameplay approaches to a popular connect-the-dots exercise for practicing line work. The left image shows the traditional exercise with pen and paper, while the right image shows one of our gameplay approaches *ZenSketch*.

INTRODUCTION

Sketching has traditionally been considered a valuable skill for professions such as industrial design, architecture, and engineering as it has been shown to benefit problem solving ability [39] and improve communication skills [7]. It is also increasingly valued in the multidisciplinary field of human-computer interaction (HCI) as a means to rapidly generate ideas for user experiences [4, 26, 42]. However, the skill relies on many different fine motor skills and cognitive skills working together [45, 46] and it can take an individual years of practice to make improvements.

It is not uncommon to find people who lack confidence in their sketching ability, and a common remark one might hear is “I can’t even draw a straight line!” This form of low self-efficacy [1] and learned helplessness is common in many people and often begins in childhood [12] as many children abandon artistic and creative activities. This low self-efficacy naturally makes it difficult to be motivated to practice. Even students studying industrial design and learning to sketch at a professional level struggle with motivation and can view practicing fundamentals as a “chore” [20].

Gamification, game-based learning, and serious games are promising areas of research which may help to motivate students in educational contexts. Serious games have shown to be more effective than traditional educational methods [54], but not necessarily more motivating. Ongoing research in these

areas is exploring the degree to which games can motivate people and in what manner [18, 27, 50, 28]. There has even been exploration in to a comprehensive design framework for gamification in order to push the emerging field towards “inspiring and empowering” gameplay versus the more sinister “manipulative and obsessive” gameplay [6].

Our goal with this research was driven by two main research questions:

R1—*What motivates individuals to practice sketching and how do those motivations change with skill level?*

R2—*How are our current approaches to sketch-based gameplay motivating students?*

To answer R1, we conducted a grounded theory study with eighteen participants, including four professionals. To answer R2, we conducted a semester-long implementation of two previously designed approaches to motivating line work practice with sketch-based gameplay in a university sketching course as well as a high school art course.

Our contributions in this work include:

- An analysis of how motivations of individuals with different sketching skill levels change and evolve. This analysis may be useful for other researchers, educators, and technologists involved in design education and/or art education.
- A framework for how various approaches to sketch-based gameplay can target these motivations and encourage sketching practice for individuals with different skill levels.
- The results of a semester-long case study of two sketch-based gameplay implementations in a university sketching course and a high school art course. We gathered interesting insights about how students engaged with our approaches and how they were motivated.

RELATED WORK

We initially describe some related sketch-based games and applications before diving in to other work in motivation theory and motivating students with games. We acknowledge that what constitutes a “game” and what does not can be quite subjective, but we borrow reasoning from Stenros [41] to define games as culturally-constructed artifacts.

Sketch-based Games

Sketch-based games are by no means a new concept. Casual classics like *Tic-Tac-Toe* and *Hangman* can be played with readily accessible pen and paper. *Pictionary* [34], a charades-inspired word guessing game that involves drawing, remains a popular board game decades after its creation.

With digital games now a prevailing medium, new sketch-based games have been created which utilize either finger swiping or the use of a digital stylus. *DrawSomething* [30], a mobile game that is very similar to *Pictionary* is worth noting for how it promotes communication skill through sketching.

Other sketch-based games have been more oriented towards education. Many have been geared towards children, e.g., the work of Paulson et al. in encouraging learning through more

tactile and kinesthetic approaches [31]. *EasySketch2* was developed to assess and improve fine motor skills in children in order to see how prepared they are for school [21]. *TAY-ouKi* [48, 47] was oriented towards teaching young children to draw basic shapes. A system developed by Truong et al. [44] helps children learn new concepts through sketch-based interaction. Wasson et al. [49] showed games can be utilized to learn art history and other general pictures.

Some games have been more oriented towards research and collecting data. *PicturePhone* and *StellaSketch* are collaborative sketch-based games that utilize human computation [24] to collect and classify sketch data [19]. Google released a game called *QuickDraw* that could guess what users were drawing using machine learning, and was meant to build a massive dataset of over 50 million doodles. These games offer fun play experiences for users while also fulfilling secondary research motives.

Sketch-based Applications

It is worthwhile to mention the many sketch-based tutorial applications that have been developed for teaching sketching skills. While they are not games, they offer interesting insights in digital approaches for improving sketching skills in people, and can inspire ways to incorporate gameplay.

Sketch Sketch Revolution [11], was a guided tutorial system for sketching that offers feedback on stroke speed and accuracy. The key insight from this work was to treat each line of a drawing as a granular element, and to offer the user a means to produce the same drawing as the tutorial creator line by line. It is not difficult to see how gameplay could be incorporated in to this as each line can serve as a core “loop” for a game.

PortraitSketch [55], *ShadowDraw* [25], and *DrawMyPhoto* [52] are tutorial systems based on computer-assisted tracing. While tracing is useful for beginners to build confidence in drawing, it is not often used as a genuine tool for improvement in pedagogy of teaching drawing and sketching [22, 35]. *How2Sketch* [17] is a more recent work that can generate step-by-step sketching tutorials from 3D Models, however it does not provide real-time feedback on performance.

ICanDraw [8] is a guided tutorial system for sketching human faces that utilizes sketch recognition and template-matching to guide the user in properly proportioning faces as they draw them. *ICanDraw* is notable for how well it encourages accuracy, an important aspect of quality drawings, and particularly important for the nuances of the human face.

Aalto Drawing is an educational tool that shows promise for “fair and encouraging” automatic accuracy feedback on a variety of basic forms [23]. While it is limited to a star rating, and has yet to be formally evaluated, it hints at the possibility of the gamification of drawing practice and its potential to motivate students.

Motivation Research

Since this work is focused on motivating individuals, it’s worth mentioning some sensitizing concepts in motivation theory that are relevant. Self-Determination Theory (SDT) [37] is one

of the prevailing paradigms in psychology, as it describes people's innate psychological needs for competence, autonomy, and relatedness. When learning a new skill, individuals tend to be more *extrinsically* motivated at first, looking for outside rewards such as positive feedback or monetary gain. However through the natural process of self-determination, motivations are internalized and the individual starts to become more *intrinsically* motivated to learn the skill. Motivation in games has been widely studied and remains an interesting area of research since games have the potential to be very immersive and engaging. Richard Bartle [2] created a taxonomy of player types for massively-multiplayer online (MMO) games that describes their motivations. We draw inspiration from this 2-axis approach to motivations.

The work of Phillips et al. [32] explored how different in-game rewards motivate people. They found little difference between individual isolated rewards, but found that a greater *variety* of rewards has a positive impact on interest and enjoyment. This is an important insight in to the design of serious games to motivate students in educational contexts.

Serious games have been shown to be more effective than traditional educational methods in terms of learning and retention, [54] but not necessarily motivation. Ongoing research in game-based learning is exploring the degree to which games can motivate students more [18, 27, 50].

MOTIVATION STUDY

In an effort to understand what motivates students to practice their sketching ability, we initially conducted a grounded theory study [5] with eighteen participants, including fourteen undergraduate and graduate industrial design students and four established industrial design professionals. Seven of the students were male, while seven were female. Figure 2 is a table that provides more detail on the participants.

Semi-structured interviews were conducted with these individuals with a primary focus on understanding what motivates them to practice sketching, and what factors hinder their motivation or discourage them. Interviews lasted approximately 20–30 minutes. Theoretical sampling [14] was used to ensure a variety of skill levels were represented as well as both males and females. The constant comparative method [13] was used to continuously update codes and categories as interviews were conducted.

Participants were asked to self-identify as being either **Novice**, **Intermediate**, or **Advanced** at sketching. Descriptions of these categories are below:

Novice—*I am still learning fundamentals and have much to improve on. I am not very confident in my sketching ability.*

Intermediate—*I have mastered some fundamentals, but am still improving and learning. I am somewhat confident in my sketching ability.*

Advanced—*I have mastered fundamentals and advanced methods and am very experienced and confident in my sketching ability.*

STUDENTS			
CODE	GENDER	AGE	SKILL LEVEL
S1	Female	25	Novice
S2	Male	24	Advanced
S3	Female	24	Intermediate
S4	Male	25	Intermediate
S5	Male	25	Novice
S6	Male	29	Intermediate
S7	Male	21	Intermediate
S8	Female	25	Novice
S9	Female	28	Novice
S10	Female	23	Novice
S11	Male	26	Novice
S12	Female	21	Intermediate
S13	Female	25	Advanced
S14	Male	22	Novice

PROFESSIONALS			
CODE	GENDER	AGE	SKILL LEVEL
P1	Male	41	Intermediate
P2	Male	42	Advanced
P3	Male	24	Intermediate
P4	Male	25	Advanced

Figure 2. A Table showing participants interviewed during our grounded theory study.

Ultimately, four categories emerged which encompass what motivates students to practice their sketching ability: *Achievement*, *Competition*, *Communication*, and *Creativity*. A high level overview of the categories can be seen in Figure 3. More detail about these categories is described in the following sections.

Achievement

Particularly prominent among the most novice students interviewed, a sense of achievement was a strong motivator for practicing sketching. This was the most extrinsic and ego-driven motivator. Some students wanted to just “feel” better at sketching, while others were looking for external praise from their instructor or peers. Some were simply driven to avoid negative criticism from their instructor or peers.

“I’ve never felt too motivated because I never get any praise from my teacher.”—S10

ACHIEVEMENT	COMPETITION	COMMUNICATION	CREATIVITY
<i>A sense that your sketches are good, in your own eyes and the eyes of others</i>	<i>A sense of having better sketches than others or being better than others at some aspect of sketching</i>	<i>Being able to produce sketches that are clear and communicate ideas well</i>	<i>Being able to produce novel ideas and forms with sketching</i>
Positive Feedback from instructor	Being the best in the class	Communicating ideas well	Generating novel ideas
Positive feedback from peers	Not being the worst in the class	Clear quality sketches	Generating novel forms
Grasping concepts	Having better looking sketches than others	Emulating professional styles	Solving problems with sketching
Liking one's own sketches			

Figure 3. The four categories that emerged from our grounded theory analysis, along with high-level codes that contributed to the categories.

"I'm afraid of my instructor criticizing me. I want to do well."—S1

Competition

Some students expressed a desire to be the best in the class, or to have their sketches highlighted during critiques. Others simply wanted to avoid being the *worst* in the class. Such motivations fall under the category of competition. There was also a consensus that if there was going to be competition, everyone should be around the same level.

"Competition can definitely motivate me, but only if they are around my skill level."—S3

"Some friendly competition and seeing my friend's sketches was always a motivator for me when I was a student."—P1

Communication

Some students were focused on the practical reasons for learning sketching such as collaborating and communicating ideas. These students tended to be more intermediate or advanced and were focused on their careers and finding jobs. From that perspective, the students were motivated by producing higher quality drawings that communicated ideas better and could be better understood by their peers.

"If you have an idea and you can't put it on paper, it doesn't count."—S6

"I'm always inspired to practice by seeing work from the pros like Syd Mead and Joe Johnston."—P1

Creativity

Some of the most advanced students and the professionals we interviewed were motivated by novelty and a desire to make the most creative ideas with sketching. The students who were most motivated by this were also approaching graduation and were focused on their careers. Since sketching and the rapid generation of ideas is a key part of the discipline of industrial design, it's no surprise that these individuals were motivated by creativity.

Interestingly, we found that the most advanced individuals also rejected competition as a motivator, with some even suggesting it can be a negative. This suggests a shift towards intrinsic mastery-driven motivation versus extrinsic ego-driven motivation. This is an ideal evolution of motivation from the standpoint of SDT [37].

"Competition is not what sketching should be about."—P4

"I've been in a position where others are discouraged because of my sketching ability, so I think it should be more about personal mastery."—S2

MOTIVATION FRAMEWORK

A fundamental insight of the grounded theory study was the realization that individual's motivations evolve based on skill level and confidence. Figure 4 shows an approximation of how individual's motivations change with skill level in a radar chart inspired by the gameplay motivation work of Richard Bartle [2], among others. We produced the charts by coding instances of each category for each participant and averaging them. While not a rigorous approach, it provides a general sense of these changes in motivation.

This insight influences a key component of our motivation framework—To employ different motivators based on an individual's self-efficacy and skill level, be it self-evaluated or determined by an intelligent system based on performance. The following sections explain this approach for novice, intermediate, and advanced individuals.

Novice

It is important for many novices to have a sense of *achievement*, providing a boost in self-efficacy and motivation that can carry over in to more time spent practicing. Achievement in the context of sketch-based gameplay can include high scores, RPG-influenced stat and skill improvements, improvements in performance metrics, and completed artifacts that evoke a sense of pride. Previous work has shown that when individuals invest time and effort in to creating something, it holds more value to them [29]. We believe it is best for novices to compete

Figure 4. These radar charts depict an approximation of how motivations evolve as one's skill level increases in sketching. Naturally, not all individuals follow this exact evolution, but it was the general trend we found. Novices are primarily in need of a sense of achievement. As they become intermediate, their motivations can expand to competition and communication. Eventually, as they master sketching and become professionals, they see sketching as a useful *tool*, and are more motivated by creativity and communication, while being less interested in ego-driven motivations like achievement and competition. This follows self-determination theory.

with themselves initially, rather than competing with peers, since many individuals expressed being discouraged when compared to peers.

Recommended motivators for Novice skill level:

- Single-player gameplay
- High scores
- Achievements / Badges
- RPG-inspired leveling / stats
- Assistance in producing quality artifacts

Intermediate

At the intermediate level, motivators can expand to include *competition* and *communication*. At this point, individuals may have developed enough sketching self-efficacy to no longer be discouraged by comparison to peers.

Friendly competition can bring out strong motivation in individuals, particularly those who already identify as being competitive. Some individuals may not identify as being competitive at all, so we believe competition should always be an *option* rather than a requirement. Competition in the context of sketch-based gameplay can include leaderboards and thematic sketching competitions.

Communication can also be a strong motivator at this stage because individuals may be starting to understand that sketching is a useful and practical “tool.” *Pictionary* and *DrawSomething* are examples of how gameplay can foster communication skills and possibly motivate someone to improve their sketching ability, although the games are not explicitly designed for that purpose. Nevertheless, the more clearly an individual can communicate an idea, the better they can perform in such games.

We recommended introducing these motivators for Intermediate skill level:

- Multiplayer gameplay
- Themed sketching competitions
- Collaborative gameplay
- Leaderboards
- Communication game mechanics

Advanced

As individuals become more advanced at sketching, they begin to tap in to their creativity and be highly motivated by producing truly novel ideas and forms. At this point it can be advantageous to use *creativity* as a motivator. Creativity in the context of sketch-based gameplay can include idea generation game mechanics, puzzles that require divergent thinking, etc.

It's also important to consider that at an advanced level, individuals can inspire others with their sketches and those that we interviewed expressed they were motivated to do so. It may be beneficial to bring in *community* aspects, and give these individuals the opportunity to both share their sketches and teach others concepts.

We recommended introducing these motivators for the Advanced skill level:

- Idea generation game mechanics
- Opportunities to share sketches
- Opportunities to teach others

Limitations

We recognize that the proposed four-component motivation model and Figure 4 are based on an exploratory qualitative analysis with students from one university industrial design program along with some associated professionals, and should be validated in future work using quantitative methodologies. We believe that the model does provide a *general* sense of the motivations of individuals with different skill levels learning

Figure 5. Screenshot of the gamified line lesson. The lesson provides some basic feedback on accuracy and a summative feedback screen, but is otherwise just a digital version of the classic connect-the-dots exercise.

sketching, however it could be improved and expanded upon with more quantitative methods such as motivation scales [33] and more rigorous studies.

CASE STUDY

We conducted a study with students who were all novice to intermediate skill levels with respect to sketching, and explored two of the core motivators of our motivation framework: *Achievement* and *competition*. We focused mostly on understanding how these motivators influenced the students, and how much they encouraged more practice. We also wanted to compare two different approaches to sketch-based gameplay for basic line work—A gamified line lesson and a serious game for practicing line work called *ZenSketch*. Both are web-based prototypes that can be used on any device with an internet connection, and are described in more detail below as well as in the companion video.

Gamified Line lessons

The gamified line lesson is based on a popular exercise in design sketching pedagogy which involves connecting dots to improve freehand line work [35, 22, 16]. This exercise promotes accurate and fluid freehand line work and is common warm-up and practice exercise in the first few weeks of a design sketching course.

We “gamified” the exercise by providing real-time feedback in the form of deviation lines in red. Feedback is important in gamification and serious games, particularly to help players self-regulate their learning and achieve the desired learning outcomes [3, 9]. We also include a 5-star score after 8 lines have been sketched and provide feedback on average precision, smoothness, and speed, all important aspects of design sketching [35, 22, 16]. See Figure 5 for more detail on the gamified line lessons.

ZenSketch

ZenSketch is an approach to the same connect-the-dots exercise influenced by game-based learning and serious games [53]. The feedback and game mechanics are influenced by stealth learning since it has been shown to help reduce user anxiety and increase performance [40]. Rather than sketching “lines,” the player is actually focused on sketching bridges for the character. The feedback comes in the form of bonuses and

Figure 6. Screenshot of *ZenSketch*. The game provides real-time line feedback and bonuses during gameplay. The game also provides summative feedback and a high score, allowing for more competitive gameplay.

individual line scores, which communicate what the player is doing correctly (see Figure 6). The summative feedback is in the form of a gameover screen which shows average performance in precision, smoothness, and speed as well as providing some tips based on these values e.g., “Sketch faster to have smoother lines!”

ZenSketch also adds a leaderboard component (see Figure 9) to motivate individuals who are competitive. Utilizing high scores and leaderboards as a motivator in games has been utilized for decades [43], particularly in arcade games where players compete for “bragging rights.”

Methodology

We implemented the gamified line lessons and *ZenSketch* in two courses for a semester-long study in Fall 2017. One course was an art course at a Giddings High School in Texas, and the other was *ID1418*, an introductory Industrial Design sketching course at Georgia Institute of Technology. All participants had access to both the game and the line lessons in a system called *SketchTivity* [51]. They had freedom to use one or the other approach, or both.

There were a total of 150 students that engaged with the systems, including 58 students from the Texas high school, and 92 students from the Georgia Tech sketching course.

We allowed the instructors to implement *SketchTivity* in their classes as they deemed suitable so as to not interfere with their teaching methodology. This encouraged more naturalistic gaming and resulted in data which could be described as *organic*. The students had access to the game and line lessons and could play them at their own leisure instead of being strictly required to play it at certain times, although the university students were encouraged by their instructors to practice periodically. The importance of this methodology was to be able to make observations on how well the approaches motivated the students.

In an effort to understand which approach students seemed to prefer, we logged lines practiced, time stamps, games played, scores, and metrics for each line including precision, smoothness, and speed data. We also conducted semi-structured interviews with three Georgia Tech students who played *ZenSketch*

extensively for more specific insights on the experiences they had while playing the game over the semester. It is important to note that we did not look at overall improvement trends because this data was very asymmetrical, however we did investigate the performance of the students who played the game extensively.

CASE STUDY RESULTS

In general, both approaches were engaging and motivating to students with 72,842 lines practiced overall and the average student practicing 243 lines (± 425.12) over the semester.

Collectively, nearly twice as many lines were practiced with the gamified line lessons (47,842) versus *ZenSketch* (25,002). This is a statistically significant difference ($p = 0.0001$) when comparing data from the two systems with a paired t-test.

The students who were highly engaged by *ZenSketch* were a minority. The students that played the game 10 or more times comprised only 26 of the 150 students, but accounted for nearly 64% of the 25,002 lines practiced in *ZenSketch*. In later sections we further investigate three of these participants.

The following results are organized in themes we found for the semester study based on analysis of the data. We did not focus on comparing activity between the two courses since the data was asymmetrical (both prototypes were used much more in the Georgia Tech sketching course where it was a requirement to practice for at least 15 minutes each week).

Overall Engagement

Figure 7. A histogram showing lines practiced over time for both *ZenSketch* and the gamified line lessons. There was a natural drop-off over time in both cases, but in October there was more lines practiced with *ZenSketch*. This happens to coincide with when the high school students used the system the most.

As one might expect, there was clearly initial excitement, but some natural loss of interest over the course of the semester. Figure 7 shows lines practiced from when they created an account and had access to the system.

Figure 8 shows lines practiced over the course of the semester in a bubble chart. It can be observed that participants tended to practice lines in sessions or “bursts.” This is likely due to motivations to improve on their score and/or the competitive aspect of the game which is discussed in the following sections.

Figure 8. Game plays of all 150 users over the semester study. Each horizontal line in the chart corresponds to a user. If multiple lines were practiced in a day (sessions) we encoded that in to bubble size. It can be observed that players tended to practice lines in “bursts,” likely in an effort to attain a better star rating (achievement) or a better rank on the leaderboard (competition).

Competition as a Positive

Figure 9. The leaderboard was found to be a highly motivating factor for some students, including participant CS1 who played the game 58 times in an effort to achieve the top score.

We found that the high score leaderboard component of the game (Figure 9) was a strong factor in encouraging repeated plays, particularly for participants who identified as being competitive.

Participant CS1 was an undergraduate student at Georgia Tech studying industrial design who was noteworthy for having played the game the most of any student—58 game plays in a period less than two months, practicing 1,711 lines, also the most of any student. We found that she was primarily motivated to play the game as much as she did because she found it “addictive” and was aiming for the high score in her class of 92 students.

“I found it was a pretty addictive game.” “There was one particular score at the top. They had a top score and I was in 2nd place or something. I was wanting to try to beat it. I could never beat it!”—CS1

Participant CS2 was another undergraduate student at Georgia Tech studying industrial design who played the game 14 times in her own effort to get the top score.

“...also having the scoreboard at the end where you can see oh this person in my class got like a million points, it

gives you a goal—I have to beat them. I got more in to it when I was trying to beat other people's scores.”—CS2

CS1 found the game to be much more appealing than the traditional connect-the-dots exercise common in the first few weeks of a design sketching course. She also found it more appealing than the gamified line lessons.

“I was doing a lot of the exercises but honestly was just getting kind of bored with it... And the game was just a lot of fun.”—CS1

CS2 felt similarly, noting that the game made her feel more accomplished.

“Having the game definitely makes motivation easier. It makes you feel like you're actually accomplishing something instead of just like doing practice for nothing.”—CS2

Competition as a Negative

One participant, an undergraduate Mechanical Engineering student from Georgia Tech whom we will identify as O1, admitted to using a laptop with a track pad instead of a stylus to achieve the highest score of all participants in both studies. The study was relatively informal and encouraged the use of any number of devices, therefore we could not account for this. We had been suspicious that this participant utilized a bug in the game to achieve her score, but she openly admitted to using her track pad in the interview.

This data was thrown out, however we believed it was important to mention as an example of how extrinsic motivators such as competing with others for a high score can sometimes lead to unintended and unwanted behavior in serious games. O1 was so motivated to achieve the highest score in her class that she bypassed the intention of the game and did not cultivate improvements in her line work through using a stylus.

Self-Perceived Improvement and Actual Improvement

Both CS1 and CS2 believed that they improved their line work by playing the game over the course of the semester.

“It could still be a little tedious at times since it was just lines. But I did feel like I was a lot more confident at drawing straight lines after that.”—CS2

We analyzed their data and found that CS1 kept precision and smoothness high while trending better in speed over time (Figure 10). CS2 improved in precision, but sacrificed smoothness and speed (Figure 11). This is consistent with a common “trade-off” that is made between precision and speed in motor control tasks in general [56, 38] and specifically in sketching [15]. People tend to sacrifice some precision in favor of speed and rapid idea generation when sketching.

This also suggests that significant *ZenSketch* gameplay does not necessarily correlate to a correspondingly significant improvement in line work. This may mean that only a moderate amount of gameplay can result in the desired improvement in line work that the game is designed for and further plays may have diminishing returns.

Figure 10. CS1 performance over 58 *ZenSketch* games

Figure 11. CS2 performance over 14 *ZenSketch* games

Translation to paper and traditional media

When asked if she felt like playing *ZenSketch* on a tablet translated to better line work on paper, CS1 responded that she believed it did.

“Oh yeah, yeah it definitely did—At least for lines.”—CS1

Other work in this area has shown it to be a very promising approach [21, 31, 36]. Independent of drawing on a tablet or paper, the user is cultivating the same fine motor skills, namely holding a precision instrument and moving it with increased confidence, precision, and fluidity.

DISCUSSION AND FUTURE WORK

This section includes lessons we've learned from this work, and general principles that could be useful for other researchers, educators, and technologists exploring how serious games, game-based learning, and gamification can motivate students.

Diving Deeper In to Motivation

Because of the intentionally open nature of the implementation and the organic use of our systems, it is difficult to more deeply understand student engagement and motivation from this data. Some things worth noting that influence these results:

- A greater number of lines can be practiced in a shorter time frame with the gamified line lessons. This may contribute

to the overall trend that more lines were practiced with the line lessons.

- The university students were required to practice at least 15 minutes a week as part of a participation grade during the entire semester, whereas the high school students had more freedom to use or not use the system over a shorter period. This may have influenced them to use the tools quite differently.
- Students may have had limited access to quality devices that allow for stylus input, influencing how they engaged with the system. This has been a concern with previous studies [20].

A more controlled study in the future, and motivation scales [33] along with more interviews could determine more nuances of how these approaches are engaging and motivating students.

Consistency with Our Motivation Framework

From the lens of our motivation framework and SDT [37], the results of the case study make sense. Most of the participants were novices with little to no exposure to sketching, so many of them may have been deterred by the competitive aspect of *ZenSketch*. While the participants we highlighted loved the game and were very motivated by it, they were a minority among the participants from the university course. They did self-identify as being fairly confident and intermediate at sketching, so this is consistent with them being open to the competitive aspects of the game and its leaderboard, where comparison to peers is inevitable.

This does not mean the competitive aspects of *ZenSketch* were a poor design choice, rather that they only engaged a certain subset of people who were likely competitive by nature and/or more confident in their sketching skill. This is why we suggest that competition be used as an *option* for gameplay, but not as a requirement. Variety is key, and some individuals may never be drawn to competition regardless of their skill level.

Utilizing Variety in Motivators

It is well known that motivations differ greatly from student to student. Even within a medium like video games, there is a spectrum of preferences from individual to individual. Based on the results of our study, as well as recent research on rewards in games [32], we recommend researchers and game designers consider as much variety as possible when creating gamified or game-based learning solutions to motivate students. This could include adaptive systems that give the ability for students to self-select what motivates them, or select whether or not they are competitive. It could also include games that offer many different motivators within the same experience such as high scores, collectible items, cooperation with others, character growth and development, etc. It's worth noting that there is no "one-size fits all" approach and that it is highly dependent on the domain and context.

Advancing Sketching Education

In order to reap the many benefits of sketching, students must practice, and educators must consider all tools available to

them to motivate their students. We believe this motivation framework can be one such tool.

We want to emphasize that this framework does not have to be limited to *digital* gameplay. Indeed, gameplay has been utilized in educational contexts long before the digital era. As was discussed earlier, sketch-based gameplay can include traditional pen-and-paper games like *Tic-tac-toe* and *Hangman*. Even modern educational approaches such as "sketch aerobics" utilize traditional media. The most important objective it to use sketch-based gameplay to motivate individuals of different skill levels to practice sketching, regardless of the particular medium used. Granted, digital media does not allow for certain advantages such as real-time feedback, more immersive experiences, and opportunities for remote gameplay.

We also want to emphasize that although this framework is oriented towards sketching in industrial design, many of the same principles are likely to hold true in other drawing contexts including fine art drawing [10], sketching in HCI [26], concept sketching [35], cartooning, etc. In all of these domains, students will struggle with motivation from time to time. Sketch-based gameplay can be a way to bring joy in to the learning experience while also sparking motivation. We encourage educators to experiment and researchers to share their findings.

CONCLUSION

We've presented a motivation study which describes how the motivations of individuals with different skill levels in sketching change and evolve as they improve. We've used that information to develop a motivation framework which can guide the implementation of sketch-based gameplay solutions to motivate sketching practice. We've also presented the results of a case study from the Fall 2017 school semester which involved the implementation of two different sketch-based gameplay approaches in a Texas high school art course and Georgia Tech design sketching course. The results showed both approaches were engaging, but that the gamified line lessons were more utilized overall. Many of the lines practiced with *ZenSketch* were from a minority of participants who were drawn to its competitive aspects. This shows some consistency with our framework, and we've offered other insights from the study that we hope can help others invested in utilizing gameplay for motivation.

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