

# Towards Activity-Centered Gamification Design

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**Abstract**—Gamification is increasingly advocated as a solution to motivational challenges across learning activities. However, given a particular learning activity, the question of how to choose relevant motivational affordances and how to incorporate them within the activity in order to evoke the desired motivational effect remains an open problem. To address this gap, we propose an activity-centered design framework for gamifying learning activities. The framework is driven by the motivational factors associated with the activity to be gamified and implies identifying potential motivators and demotivators with the intent to guide the selection of relevant motivational affordances. The purpose is to enable a gameful experience by choosing motivational affordances that are in congruence with the motivators while curbing the effect of demotivators. The application of the framework is illustrated by a case study complemented by an empirical evaluation.

**Keywords**—gamification, gameful, motivation, gamified learning

## I. INTRODUCTION

As motivation influences students' learning behavior it is a critical factor for students' success [1]. However fostering motivation reliably remains an elusive task. Hence, selecting effective strategies to engage and motivate students remains a challenge for many educators. As part of the efforts for finding a way to foster motivation [2, 3], gamification has emerged as a potential strategy to boost students' motivation [4]. The underlying idea of this approach is to motivate individuals by means proven to be effective in games. These include game principles, such as immediate feedback and freedom to fail, and game design elements, such as challenges, rewards, competition and progression. While the interest in applying gamification in education is growing, given its potential to enhance and sustain students' motivation, a recent review of educational gamification reveals a scarcity of research on practical methods for gamifying learning [5]. Most gamification-related studies neither report what motivational goals have been targeted nor the framework guiding the gamification design. Further they do not report on specifics, such as for what purpose particular gamification features have been selected. This inadequacy has led to slow progress in the understanding of how to practically design and implement gamified learning activities.

A common approach in gamifying learning is to focus on selecting and incorporating some game elements (typically points, badges and leaderboards) in a learning activity that targets some learning outcomes. This approach follows the pattern observed in some other fields, such as marketing, healthcare or fitness. However, motivating students to complete learning activities is more challenging than motivating customers to submit reviews, patients to take their medications on time, or adults to perform their exercises regularly. In those cases, motivation associated with the performed activities is more amenable to influence by external factors. Learning, in contrast, is a complex, active, and

typically lengthy process that can give rise to a variety of demotivating factors. As such, it requires stronger inner motivation and purposeful effort.

For learners, motivation to engage and persist in an activity stems from different sources, a significant one of which is the learning activity itself. Learning activities are characterized by features with positive impact on learners' motivation (motivators), such as acquiring useful skills, as well as by features with negative impact on their motivation (demotivators), such as uninteresting content or a high level of difficulty for a task. To account for these factors, we propose an activity-centered gamification design (ACGD) approach, which puts the emphasis in the design process on the activity to be gamified. The motivation and demotivation related to learning activities [2], can provide a framework for a meaningful gamification design.

In the context of information technology and of gamification in particular, the affordance concept has been adopted [6] for conceptualizing the motivational properties of systems. We will use the concept of motivational affordances to refer to those properties of a system that afford motivation. In this context, gamification can be viewed as an approach of using game design elements to engender motivational affordances in a system. We will use the term "motivator" to refer to those factors which, when present, cause willingness to engage in an activity and the term "demotivator" to factors which cause unwillingness to engage in an activity.

Gamifying learning activities is a complex and ambiguous task. It deals with learners with different (frequently unknown) personalities and learner types. It further deals with activities that have different motivational characteristics and values, as perceived by the learners. The proposed ACGD framework is intended to reduce the complexity of this task, while also reducing its ambiguity. Basically, we can view each activity as an object characterized by its motivators and demotivators. The motivators and demotivators can be seen as input to a method, which helps identify the motivational affordances of the targeted gamified activity. While a learner's type is typically unknown, targeted activities are known in advance. Although the motivators and demotivators are subjective, there is a significant degree of commonalities that generally allow the creation of a practical model covering a good proportion of the involved learners.

The proposed ACGD framework emerged from the insight that the gameful experience, as a driver of the desired outcomes of the gamified activity, should (partially) come from the motivational features characterizing the activity itself. The decision to gamify a particular learning activity is typically triggered by the desire to engage students in that activity, which implies enhancing their motivation for engaging in it. This, in turn, suggests understanding the motivational and demotivational factors related to the activity,

so that the motivational affordances incorporated in the gamified activity create a gameful experience as a co-effect of addressing these motivators and demotivators. According to the proposed framework, the entire process of gamifying a targeted activity should be governed by that goal.

A distinctive feature of the proposed ACGD approach is that it provides a starting point for the targeted gamification, namely, identifying the motivators and demotivators for the learning activity. This accounts for the fact that in addition to the positive influences that can promote learner's motivation, there are many demotivational factors that have a negative impact on it [7] and may disturb the intended effect if not addressed adequately. The activity-centered gamification design framework is the main contribution of this paper. In the next section we discuss the underlying motivations and assumptions leading to the proposed ACGD framework.

## II. DESIGNING FOR MEANINGFUL GAMEFUL EXPERIENCE

At the heart of our approach to gamifying learning is supporting learners' gameful experience. The gamification of learning activities should not be driven by employing certain game elements. Instead, it should be aimed at enhancing the learning environment with affordances that provide gameful experience for learners. Gameful experience occurs when learners are engaged in meaningful, fun, and achievable goals that motivate them to participate voluntarily in the learning activity. According to [8], it is the gameful experience afforded by the activity that drives its effect on learners' behavior. More important, the emergence of the gameful experience is necessary to reach the intended goal of gamifying [8, 9]. Therefore, gameful experiences must be in focus when designing the gamification of learning activities. However, given a particular learning activity, the question of how to structure it, how to choose relevant motivational affordances, and how to incorporate them in the activity to evoke the desired gameful experience remains an open problem.

Several authors [8, 9] have tried to describe the concept of "gameful experience" from different perspectives. While in [8] the focus is on measuring gameful experience, the authors of [9] have proposed a definition centered on psychological characteristics that lead to gameful experiences. Essentially, the definition asserts that a gameful experience depends on the occurrence of three psychological states: (1) a perception of non-trivial and achievable goals, (2) the motivation to pursue these goals under (somewhat restrictive) rules, and (3) the belief of voluntary participation. From this point of view, a gamified activity only carries the potential to create a gameful experience. The critical part of this definition of gameful experience is the motivational part assuming a volition to pursue the (activity's) goal. If a user is not motivated to pursue the goal, then gameful experience will not occur for that user.

Not all activities can be easily redesigned to provide affordances for gameful experiences. An example is academic research, a creative activity for which there is an established form of recognition, based on the number of citations. If your goal is to get more citations, there is no motivational affordance which will cause that. Practicing solving problems in an academic subject, on the contrary, is suitable for such a redesign. This learning activity is typically voluntary and assumes an adequate set of problems with different levels of difficulties for learners with varying levels of skills. Therefore, practicing meets the first and third conditions for gameful experience. Yet, many students don't practice outside the

classroom and those who practice often are not driven by any gameful experience. The missing condition in conventional practicing, which is essential for affording gameful experiences, is a set of rules specifying the goals and how these goals can be achieved. Yet, through feedback, the rules should afford the users with motivation to pursue those goals.

As can be seen from the definition in [9], the second condition does not mention the gamified activity. However, when gamifying a particular activity the incorporated goals and rules are not independent of the activity. For example, in a gamified fitness activity, the rule for awarding a badge may specify walking at least 10,000 steps, while in practicing the rule for awarding a badge may specify solving problems at least 5 consecutive days. In both cases, the semantics of the rules is a function of a specific action in the gamified activity. Basically, such type of rules link a utilitarian activity to hedonic values with the purpose of affording motivation through gameful experience. Hence, the actions in the activity are part of the "game dynamics" and gameful experience can only emerge through acting accordingly (e.g. practicing) in the gamified activity. Therefore, the actions targeted in the gamified activity are also preconditions for creating the gameful experience. Based on these observations, we argue that the emergence of gameful experience depends on both the motivational characteristics of the activity and the incorporated motivational affordances.

Unlike games, the gameful experience in gamified activities is a supplemental quality anticipated to occur as a result of enhancing the activity with motivational affordances (through relevant rules). Actions in the activity require some efforts, and efforts require motivation. Therefore, the emergence of gameful experience depends also on the motivators characterizing the activity and driving the users' efforts. For example, in gamified practicing, the gameful experience may be driven by the level of achievements (e.g. the number of collected badges) and competition (e.g. the position in the leaderboard), which are a function of the effort put in practicing.

According to [10], motivation depends on the person and the type of activity, with levels of motivation varying from person to person and from task to task. Notably, the focus in the motivational research has been mostly on the subjective nature of motivation. Since motivation is embodied in the relation between an individual and an activity, motivation can be defined in terms of the activity being motivating or as an individual's motivation towards the activity. Accordingly, each activity is associated with some motivators and demotivators as perceived by the involved individuals. As gamification is applied to a particular activity, the related motivators and demotivators can be used as guiding points in the design of a gameful experience with this activity, that is, in gamifying the activity. Interestingly, both the activities and the concept of gameful experience, as defined in [9] ("the motivation to pursue these goals under (somewhat restrictive) rules"), are characterized by motivational factors. Since they share a common goal, the intended meaning of their motivational qualities should reflect potential dependencies. This is the core of the proposed gameful activity design. This viewpoint is also in line with the concept of meaningful gamification [11], which emphasizes the connections between game elements and certain aspects of the activities that are of importance to the individuals. An action that has significance and meaning is motivating.

The second condition of the definition of gameful experience [9] entails presence of motivation to pursue the goals following the specified rules. In a particular gamification context, such rules link certain actions in the gamified activity to game-related goals and thus to the corresponding motivational affordances. If learners are not motivated enough to engage in pursuing the goals while following the specified rules, because of inadequate motivational affordances, then gameful experience will not occur. On the other hand, the gameful experience afforded by the gamified activity is what drives the effect on users' behavior. This effect is the whole purpose of gamification. Hence, a closer look at the definition of gamefulness led us to the following observation: rule-based actions in the gamified activity (potentially) drive the gamefulness – gamefulness drives the desired actions. Therefore, to enter and continue this circular process, the motivators and demotivators of the activity to be gamified need to be identified and examined. The objective is to determine the targeted motivational affordances based on the identified motivators and demotivators. This lays the foundation of the proposed framework of activity-centered gamification design.

### III. DESCRIPTION OF THE ACTIVITY CENTERED GAMIFICATION DESIGN

In the following, the term game (design) elements will be used from the viewpoint of the motivational affordances they provide. According to the proposed activity-centered framework, for each motivator/demotivator associated with the activity to be gamified, the designer shall identify motivational affordances that align best with it. The framework implies that we know the motivators and demotivators of the activity, as well as the available motivational affordances. The phrase “align best” carries an important meaning and denotes a multi-step process. This multi-step process reduces the goal of gamifying a particular activity to a set of sub-goals linked to the identified motivators and demotivators. As a result, it reduces the complexity of the original task by breaking it into a set of sub-tasks where the goal of each subtask is to choose a motivational affordance in alignment with the motivational effect for the respective motivator/demotivator. The available set of motivational affordances depends on the design goal and may originate from various sources, such as the employed gamification platform or other implementation options, the desired motivational effect, or a suggestion from a relevant study. A comprehensive list of common categories of motivational affordances is proposed in [12]. In addition to making the gamification meaningful by focusing on motivational factors of the activity, this design process affords the intended gameful experience. (Here we assume that the activities are voluntary and offering non-trivial and achievable goals).

The proposed framework of activity-centered design includes the following steps.

1. Identify the motivators and demotivators associated with the activity to be gamified.
2. Group the identified motivators into intrinsic and extrinsic.
3. Group the identified demotivators by sources of demotivation.
4. Consider in turn each motivator and identify motivational affordances from an available set (such as

the one proposed in [12]) that afford reinforcing the effect of that motivator.

5. Write a short description of the intended effect of the chosen motivational affordance(s).
6. Consider in turn each demotivator and identify motivational affordances from the available set that afford curbing the effect of that demotivator.
7. Write a short description of the intended effect of the chosen motivational affordance(s).
8. Consolidate the selected affordances by removing duplicates.
9. Using the selected implementation option (e.g., a gamification platform) implement the final list of motivational affordances following the corresponding descriptions.

In the following, we outline the rationale behind the proposed steps. The identification step is fundamental. It may combine instructors' past teaching experience related to the learning activity to be gamified with results from relevant students' surveys or related studies. All subsequent steps build on the identified motivators and demotivators of the activity.

Since intrinsic and extrinsic motivations play different roles in gamification they should be considered separately. Note that “reinforcing the effect of the motivators” has a different meaning when applied to intrinsic (vs. extrinsic) motivators. Intrinsic motivators (e.g., evoking curiosity or pleasurable experience) are part of the drivers of the gameful experience, which suggests reinforcing their motivational effect with appropriate motivational affordances and rules. For example, the “feeling of achievement” motivator instigated by a practicing activity can potentially be reinforced by motivational affordances fostering a sense of accomplishment. On the other hand, motivational research has shown that more autonomous forms of extrinsic motivation are associated with a greater involvement, engagement and satisfaction [10]. This finding suggests using design strategies having the potential to shift the considered motivators towards more self-determined forms of extrinsic motivation and leading to internalisation of the extrinsic motives. For example, using virtual currency earned through practicing, which can be spent for course benefits in a course shop, can create a perception of ability to mitigate some negative outcomes in the future. Such a perception of increased ability to control the unpredictability of negative course outcomes provides an additional sense of autonomy.

Learners face a variety of demotivational influences when practicing [7]. Past research has revealed that demotivation emanates from different sources [13]. In a learning context specifically, demotivators can be grouped in three main categories:

- Attitudinal: capturing attitudes towards the value of the activity, its interestingness, difficulty, provided help, etc.
- Ability/interest related: capturing factors related to the achievability of the activity, such as lack of required skills/knowledge, lack of confidence, lack of interest.
- External to the activity: capturing external barriers, such as lack of time, lack of interest in learning, laziness, etc. As the sources of external demotivators

are mostly outside the activity, they are out of scope of the ACGD framework.

The proposed categorization of demotivators groups them by reasons for unwillingness to engage in the activity, with the aim to facilitate the process of selecting the motivational affordances and writing descriptions of the intended effect on the corresponding demotivator.

The short descriptions are intended to serve as brief specifications of how the targeted motivational experiences are to be achieved with the selected motivational affordances and with the available implementation option in mind. The insight is to link the motivational affordances to *declarative statements* that can play the role of a bridge between the design and the implementation step. The list of motivational affordances obtained after the consolidation step should be examined from the viewpoint of the goals of the gamified activity. The examination step reveals which motivational affordances are necessary and which are unimportant or redundant, resulting in a final list to be passed to the implementation step.

The final step in the ACGD approach is the implementation step which includes incorporating the selected motivational affordances in the gamified environment. It involves defining rules that specify the behavior of the selected game element following the descriptions of the intended effect. Since this step may require certain adjustments, it might involve several iterations to reach the desired effect. In addition, it may require an extension or reconstruction of the original learning content (e.g., adding a set of easy or challenging problems in response to the derived motivational affordances). Although not required by the ACGD approach, this step would be considerably facilitated if a gamification platform is used that supports the selection of appropriate game elements along with rules defining their functioning.

The proposed activity-centered gamification design is based on the accumulated experience of gamifying a Data Structures course over a span of four semesters. In the next section we exemplify the ACGD approach in the context of gamifying that course with a focus on the practicing activity.

#### IV. APPLYING ACTIVITY CENTERED GAMIFICATION DESIGN TO PRACTICING

The Data Structures course was gamified by using the course gamification platform OneUp [14]. OneUp provides support for instructors to create automatically checked static and dynamic practicing problems and to incorporate established game design principles and elements in their instructional methods. The following game elements are supported: experience points (XP), skill points, progress bar, avatars, leaderboard, skill board, badges, virtual currency, content unlocking, activity streaks, goal setting, challenge duels, call outs, learning dashboard, and chat. The platform is highly configurable and supports learning analytics and visualization to inform students and instructors of student performance and progress. The primary goal of gamifying the Data Structures course was to motivate learners to develop their knowledge by practicing with OneUp practice quizzes (called warm-up challenges). Thus the activity in the center of our discussion of the ACGD approach is practicing.

Students are driven to practice by different motivators and demotivators. The frequently observed low level of use of

practicing tools indicates the existence of a significant number of practicing demotivators. For example, many students cannot maintain their motivation for practicing because they perceive it of low importance for the course grade. For others, the motivation starts to fade with time, in particular when they practice irregularly. The analysis of the potential motivators and demotivators suggests that maintaining students' motivation requires the use of targeted strategies.

##### A. Identifying Motivators

The first step of the proposed approach was to identify the motivators and demotivators associated with the practicing activity. To do this, we started by using our own long instructional experience and also interviewed colleagues teaching programming classes. The result is presented in Table 1. In line with relevant motivational theories [10,14], we marked the motivators as intrinsic (i) and extrinsic (e).

TABLE I. IDENTIFIED MOTIVATORS AND DEMOTIVATORS FOR PRACTICE

|                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Motivators</b>   | M1: Improve practical skills in some course topics (i)<br>M2: Feeling of being challenged (i)<br>M3: Feeling of achievement (i)<br>M4: Checking understanding (i)<br>M5: Feeling of curiosity (i)<br>M6: Receiving feedback (i)<br>M7: Feeling of game-like experience (i)<br>M8: Pass exams (e)<br>M9: Improving test performance (e)<br>M10: Boosting course grades (e)<br>M11: Passing the class (e)<br>M12: Liking competition (i)<br>M13: Getting awards (e)<br>M14: Collecting awards (e)<br>M15: Demonstrating my abilities to others (e)<br>M16: Showing engagement to the instructor (e) |
| <b>Demotivators</b> | D1: Practice perceived of low importance for course grade<br>D2: Practice perceived unimportant for course performance<br>D3: Lack of necessary skills<br>D4: Lack of help<br>D5: Lack of confidence<br>D6: Trying without success<br>D7: Challenges perceived as difficult<br>D8: Challenges perceived as boring<br>D9: Conflict with more preferred activities<br>D10: Lack of time<br>D11: Insufficient incentives<br>D12: Lack of interest in trying new things<br>D13: Lack of interest in practicing                                                                                        |

The activity-centered gamification design is likely to bring about a greater motivational effect if each of the identified motivators and demotivators is perceived as actual one by (a

non-trivial group of) learners. Thus, the second stage in our identification step was to conduct a student survey, in order to collect empirical data for estimating which of the initially identified motivators and demotivators are confirmed by learners and to what extent. We conducted the survey in the Data Structures course and a Database Management course in the spring of 2018. The survey included questions addressing the motivators and demotivators given in Table 1.

22 students responded to the questionnaire. The responses (see Fig. 1 and Fig. 2) illustrate that all of the originally identified motivators were perceived as actual motivators by at least some of the students, from 74% (for M1, M3) to 17 % (for M13, M14). Similarly, the identified demotivators were perceived as actual demotivators by a varying proportion of students, from 48% (for D10) to 5 % (for D2, D12, D13). There were no suggested motivators or demotivators that the students didn't recognized as such. In addition, the students did not suggest any additional motivators or demotivators. Thus, the study confirmed and validated the motivational drivers for the practicing activity drawn from our experience and highlighted the significance of the activity-engendered motivators and demotivators from learners' point of view.

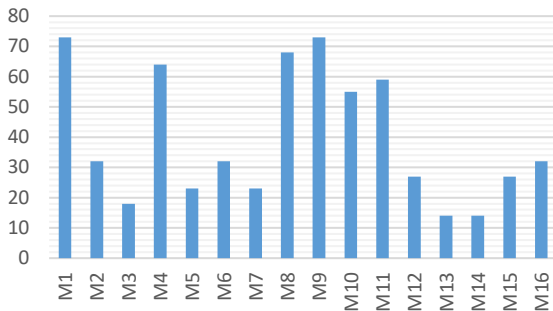


Fig. 1. Responses to the practicing motivation questions.

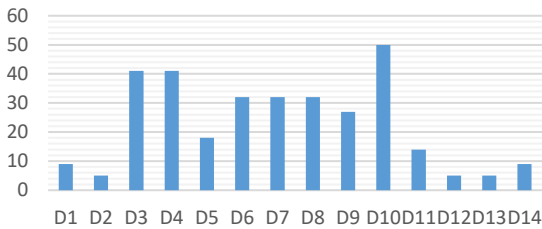


Fig. 2. Responses to the practicing demotivation questions.

### B. Deriving Motivational Affordances

This part of the proposed framework covers the multi-step process of choosing motivational affordances with potential to reinforce the effect of identified motivators and to curb the effect of demotivators. The supporting insight (confirmed by the survey) is that most students are driven by similar motivators and impacted by similar demotivators. Therefore, gamifying an activity through ACGD could increase the likelihood of a positive reception of gamification. For guiding the selection of motivational affordances that align with the identified motivators and demotivators we used an adapted version of the twelve-dimensional categorization of motivational affordances proposed in [12]. The resulting alignment for the identified motivators (split into intrinsic and extrinsic) is shown in Table 2.

TABLE II. MOTIVATORS AND THE CORRESPONDING MOTIVATIONAL AFFORDANCES WITH THEIR DESCRIPTORS

| Intrinsic motivators               | Motivational affordances with their descriptors                                                                                                                                         |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Feeling of being challenged        | <i>Increasing Challenges</i> : Offer challenges with increasing difficulty levels to match learners' knowledge and skills.                                                              |
| Feeling of achievement             | <i>Rewards + Feedback</i> : Offer rewards for different types of accomplishments and allow learners keep track of their achievements and advancements.                                  |
| Checking understanding             | <i>Help/Feedback</i> : Tell learners what was incorrect and provide help to find the correct answer (if necessary).                                                                     |
| Receiving feedback                 | <i>Feedback</i> : Provide immediate and meaningful feedback including information about student progress.                                                                               |
| Feeling of curiosity               | <i>Unlocking + Unpredictability</i> : Offer content unlocking and unexpected variability in the offered rewards.                                                                        |
| Feeling of game-like experience    | <i>Competition + Scarcity</i> : Offer game-like experience through challenging classmates (e.g. on duels) or awards that are rare or difficult to obtain.                               |
| Liking competition                 | <i>Competition</i> : Allow learners to compare themselves with others or challenge other learners.                                                                                      |
| Extrinsic motivators               | Motivational affordances with their descriptors                                                                                                                                         |
| Boosting course grades             | <i>Feedback + Virtual Economy</i> : Show learners the performance, progress, and achievements. Allow learners to earn virtual currency (VC) and exchange it for course benefits.        |
| Pass exams                         | <i>Feedback + Virtual Economy</i> : Show learners the performance, progress, and achievements. Allow learners to earn VC and exchange the result of their efforts with course benefits. |
| Passing the class                  | <i>Feedback + Virtual Economy</i> : Show learners the performance, progress, and achievements. Allow learners to earn VC and exchange it for course benefits.                           |
| Improving test performance         | <i>Feedback + Virtual Economy</i> : Show learners the performance, progress, and achievements. Allow learners to earn VC and exchange it for course benefits.                           |
| Getting awards                     | <i>Rewards</i> : Offer rewards for different levels of achievements along with surprising rewards.                                                                                      |
| Collecting awards                  | <i>Rewards</i> : Offer rewards for different types of effort which are proportional to the invested efforts, improvements, and persistence.                                             |
| Demonstrate my abilities to others | <i>Competition + Achievements</i> : Allow learners to compete and demonstrate achievements.                                                                                             |
| Show engagement to the instructor  | <i>Feedback</i> : Offer feedback showing learners and instructor where the learners stand.                                                                                              |

TABLE III. DEMOTIVATORS AND THE CORRESPONDING MOTIVATIONAL AFFORDANCES WITH THEIR DESCRIPTORS

| <b>Attitudinal Demotivators</b>                       | <b>Motivational affordances with their descriptors</b>                                                                                                                                                      |
|-------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Practice perceived of low importance for course grade | <i>Feedback/Graspable-Progress/Dashboard:</i> Provide learners with information about their engagement and achievements as well as information for reflection on their learning goals and self-improvement. |
| Practice perceived unimportant for course performance | <i>Feedback/Graspable Progress/Dashboard:</i> Provide learners with information about their engagement and achievements as well as information for reflection on their course performance and efforts.      |
| Perception of lack of help                            | <i>Help + Graspable Progress:</i> Help learners identify incorrect steps and offer them hints on how to progress if necessary.                                                                              |
| Challenges perceived as boring                        | <i>Competition + Scarcity:</i> Offer game-like experience through challenging classmates (e.g. on duels) and awards that are rare or difficult to obtain.                                                   |
| Perception of insufficient incentives                 | <i>Virtual Economy:</i> Allow learners to earn VC and exchange it for course benefits.                                                                                                                      |
| <b>Skill/Interest related Demotivators</b>            | <b>Motivational affordances with their descriptors</b>                                                                                                                                                      |
| Lack of necessary skills                              | <i>Help:</i> Offer help to unskilled learners as they take their first steps.                                                                                                                               |
| Lack of confidence                                    | <i>Achievable Challenges + Rewards:</i> Offer achievable challenges for learners with different skill levels and reward the initial improvements and progress.                                              |
| Trying without success                                | <i>Help + Graspable Progress:</i> Help learners identify incorrect steps and offer them hints on how to progress if necessary.                                                                              |
| Lack of interest in practicing                        | <i>Rewards + Unpredictability + Competition:</i> Offer game-like experience through encouraging and surprising rewards along with challenging classmates (e.g. on duels).                                   |
| Conflict with more preferred activities               | <i>Loss aversion + Reward:</i> Reward learners who have completed a targeted action for a specified number of consecutive days.                                                                             |

Similarly, the alignment for the identified demotivators (split into attitudinal and skill/interest related) is shown in Table 3.

### C. From Motivational Affordances to Implementation

The final stage of the proposed framework targets the implementation of the identified motivational affordances in line with the associated descriptions. The implementation phase commonly depends on a number of implementation specifics originating from the adopted environment. Usually, a gamification platform is used to implement the gamification. Alternatively, the motivational affordances can be implemented from scratch and used in a gamified activity. The ACGD framework is independent of any specific

implementation, but for the purpose of presenting the implementation phase of the gamification of practicing, we will refer to the OneUp platform, which was used in gamifying the Data Structures course. For more details see [15, 16].

In the previous step, motivational affordances along with associated descriptions were selected with the gamification features provided by OneUp in mind. The game elements to be used in the Data Structures course included: feedback, points (XP and skill points), badges, virtual currency (VC) and leaderboard. Making the practicing activity more gameful involved also some structuring of the practice exercises. The following is a short justification of the related selections and implementation decisions.

A big part of the motivational affordances related to feedback are implemented by using the OneUp dashboard. This dashboard displays the experience points, practice points and course bucks students have earned so far. A central piece in the dashboard is the progress bar, which consists of four parts displayed in different colors: the course points earned so far, the course points that can be earned in the future, the points already lost, and the learning predictor, showing the total amount of points that would be earned in this course if the student keeps the same level of performance. The dashboard also shows the skill analytics and the student's results of taking warm-up challenges. Finally, it presents all badges earned by the learner. It provides a holistic view of the individual performance of each student with an intention to play a dual role of an informational and motivational mechanism.

The chosen motivational affordances and related structuring of the practicing activity are facilitated by the OneUp authoring support and, in particular, by the support for automated creation of dynamic problems from parameterized templates. The OneUp rule engine allows specifying adequate feedback on a challenge completion and thus conditions for cycles of engagement.

The motivational affordances related to promoting the role of practicing are implemented by using the OneUp virtual economy, which creates opportunities for earning 'course bucks' and spending them for purchasable course related 'goods'. Effectively, it elevates the perceived role of practicing within the course due to the possibility of using the bucks earned through practicing to progress or perform better in the course. In addition, allowing learners to choose how they spend the currency increases their sense of autonomy, which has an intrinsic motivational value.

The motivational affordances related to making practicing more gameful are implemented by using several gamification elements supported by the OneUp platform. These include leveling, content unlocking, random surprises in the process of practicing, as well as support for students to challenge their classmates through individual duels and class call-outs.

The motivational effect of gamification depends not so much on the number of employed game elements, as on the interplay between curiosity, challenges, accomplishments, and rewards and activity motivators and demotivators. The OneUp rule engine enables translating many of the declarative descriptions into a set of rules, which define the reaction of the game engine in response to particular situations arising in the gamified environment. Table 4 exemplifies the translation of some of the targeted motivational affordances (in line with the

associated descriptors) into rules as part of the gamified practicing implementation with OneUp.

TABLE IV. EXAMPLES OF ONEUP RULES IMPLEMENTING A SET OF MOTIVATIONAL AFFORDANCES AS SPECIFIED BY THE DECLARATIVE DESCRIPTIONS

| Motivational affordances                                                                                                         | OneUp Rules implementing motivational affordance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Rewards</i> : Offer rewards for different levels of achievement along with surprising rewards.                                | <p><i>VC: First WarmUp 30</i>: You will earn 5 course bucks if you take your very first warm-up challenge with a score &gt; 30%.</p> <p><i>VC: First WarmUp 70</i>: You will earn 7 course bucks if you take your very first warm-up challenge with a score &gt; 70%.</p> <p><i>VC: Random 75 Weekly Award</i>: At the end of each week, OneUp will randomly give 1 course buck to a student who has taken a warm-up challenge with a score &gt; 75% in the first attempt.</p> <p><i>Badge: Leaderboard Topper</i>: To earn this badge you must be on the leaderboard for four consecutive weeks.</p> <p><i>Badge: The Highest Earner</i>: To earn this badge you have to earn the highest amount of VC for the last 2 weeks.</p> <p><i>VC: Random Weekly Award</i>: At the end of each week, OneUp will randomly give 1 course buck to a student who has practiced that week.</p> |
| <i>Loss aversion + Reward</i> : Reward learners who have completed a targeted action for a specified number of consecutive days. | <p><i>Badge: Persistent Practice Level I</i>: To earn this badge you must complete 20 distinct warm-up challenges.</p> <p><i>Badge: Persistent Practice Level II</i>: To earn this badge you must complete 30 distinct warm-up challenges.</p> <p><i>VC: N Days Practice</i>: You will earn N course bucks if for N consecutive days you take at least 2 unique warm-ups with a score &gt; 70% per day.</p> <p><i>Badge: The Longest Practice Streak</i>: To earn this badge you must have the longest streak of practice days in the class for a period of 1 week.</p>                                                                                                                                                                                                                                                                                                            |

## V. EMPIRICAL STUDY

To gain an insight into how the proposed ACGD framework impacts the gamifying of student practicing, we conducted a study involving student surveys and analysis of data related to student practicing activities from OneUp's log.

### A. Student Survey

To capture students' opinion on gamified practicing we conducted a series of surveys (Spring 2018, Fall 2018, and Spring 2019) gathering information about the perceived motivational effect of practicing with OneUp. A total of 76 students responded to the survey, which included questions based on the standard Student Course Engagement Questionnaire [18]. The questionnaire uses a 5-point Likert scale. The following is an excerpt from the questions.

- Q1. I felt more effective in self-learning when practicing with OneUp.
- Q2. Practicing with OneUp made it easier for me to prepare for the tests.
- Q3. Practicing with OneUp helped me to improve my grades.

- Q4. When taking a warm-up I put in effort to complete it.
- Q5. I do not take the challenges in OneUp very seriously.
- Q6. When taking a warm-up I do not pay much attention to my performance.

Fig. 3 presents a graph capturing students' responses to these questions. Of particular interest are the responses to questions Q1, Q2, and Q3, which are related to the perceived role of practicing, as traditional practicing was perceived of low importance for the course performance (one of the strongest demotivators). The answers indicate that many students perceived practicing with OneUp as very useful in terms of both self-learning and improving course performance, with particularly high scores of 'Strongly Agree' (Q1 - 56%, Q2 - 88%, Q3 - 64%) and 'Agree' (Q1 - 80%, Q2 - 48%, Q3 - 50%). We interpret these results as an indication of a positive attitudinal shift in a big portion of the involved students caused by the attention on overcoming demotivators as part of the proposed ACGD framework's motivational strategies.

As engagement is regarded as a key indicator of learners' motivation [18], the last three questions were intended to estimate learners' engagement with OneUp practicing. The corresponding responses (where more than half of the respondents either agree or strongly agree) signal a positive level of engagement. We interpret these outcomes as an evidence of the combined effect of the incorporated motivational affordances: creating a gameful experience along with reinforcing (curbing) the impact of the motivators (demotivators).

### B. System logs

Our study spanned four offerings of the Data Structures course, with a control group (Fall 2017, 16 students) using OneUp only as a practice platform, and an experimental group (Spring 2018, Fall 2018, Spring 2019, 33 students) using the Data Structures course gamified as previously described. The collected log data showed a significant increase of the taken warmup challenges by the experimental group. Fig. 4 shows the percent of students who have taken warm-up challenges in the intervals 1-10, 11-20, 21-50, 51-80 and more than 80 challenges for both groups.

As evidenced in Fig.4, the difference in the number of warm-up attempts is pronounced: 25% of the students from the control group have not taken warm-ups at all and none of them have taken more than 20 warm-ups. In the same time, 15% of the experimental group students have taken between 21 and 50, 27% between 51 and 80, and 36% more than 80 warm-ups.

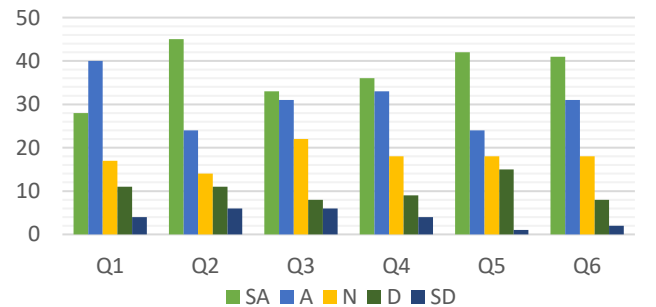


Fig. 3. Aggregated responses to the above questions (Strongly Agree (SA), Agree (A), Neither agree nor disagree (N), Disagree (D), Strongly Disagree (SD)).

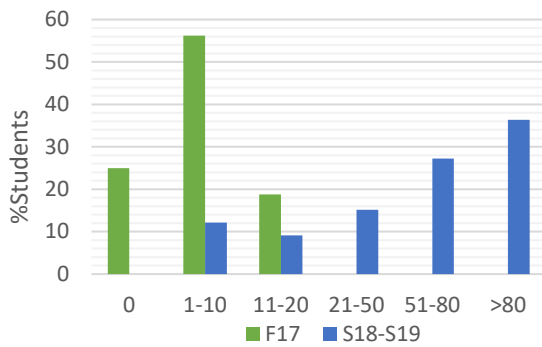


Fig. 4. Warm-up challenges in gamified/non-gamified versions.

The average number of warm-up challenge attempts for the control group was 4.5625, while the average number of challenge attempts for the experimental group was 74.6667. The Welch Two Sample t-test ( $t = -6.195$ ,  $p\text{-value} = 4.829e-07$ ) shows that the difference is statistically significant. These results further confirm that although the activity motivators/demotivators remain unchanged, after the gamification intervention following the ACGD approach, students' practicing has intensified significantly.

#### VI. LIMITATIONS

The proposed ACGD framework is based on several assumptions related to the three phases of the proposed approach: identification, alignment and implementation. The first assumption is that the set of motivators and demotivators associated with a particular activity can be identified with a reasonable reliability. The second one is that given a particular set of motivators and demotivators the alignment process will produce similar results. The final assumption is that a set of motivational affordances along with their descriptors will result in similar implementations. Here we acknowledge that there is a certain degree of arbitrariness in each of the three phases, which can be minimized using an appropriate strategy. For example, the reliability of the identification step can be improved by using a group agreement strategy (involving instructors and students). In any case, identifying motivators/demotivators for a given activity is a less ambiguous task than identifying directly the motivational affordances with a desired motivational effect for the activity. Also, there are restrictions on the arbitrariness of the choice (e.g., limited to a set of motivators and a set of motivational affordances). At the same time, the limitations of the approach offer avenues for future research. An interesting research question in this aspect is to what degree the alignment and implementation phases can be automated.

#### VII. CONCLUSION

While gamification is gaining popularity in education, available sources providing practical guidance on how to gamify learning are scarce and fragmented. This paper attempts to bridge this gap by proposing an activity-centered design framework for designing and implementing gamified learning activities. The framework is based on the gamification research suggesting that psychological outcomes depend on both the gamified activity and the gamification type. It proposes an approach for selecting motivational affordances targeting the intended engagement loops driven by the motivators and demotivators of the activity. The purpose is to create a gameful experience by choosing motivational affordances reinforcing the effect of motivators while curbing

the effect of demotivators. The framework follows a stepwise approach with three phases: identification, alignment, and implementation, where the output of one phase is used as an input for the next phase. Its application has been exemplified by showing the design and implementation steps of ACGD framework in the context of gamifying practicing activities, as part of a gamified Data Structures course, followed by an empirical evaluation of its motivational effect on learners.

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