# A Multidisciplinary, Multifaceted Approach to Improve the Computer Science based Game Design Education: Methodology and Assessment

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## ABSTRACT
In this paper, we introduce a multidisciplinary and multifaceted pedagogical approach to enhance game design education in computer science curriculum and assess its effectiveness using outcomes from Microsoft US and World Imagine Cup competitions in the game design category. We offer team project-based courses that cover multiple disciplines such as computer science, art and animation, game design, production, and business and entrepreneurship. Our students gain fundamental knowledge and skills from the multidisciplinary approach and utilize them to undergo a systematic game development process over two semesters. We also implement a unique grading system that includes ranking duels to promote the competitiveness among students which ultimately improves the quality of every game designed in our courses. We successfully demonstrate the effectiveness of our approach with results from the Microsoft Imagine Cup competitions – dozens of our student teams have been nationally and internationally recognized in the past eight consecutive years.

## Categories and Subject Descriptors
K.3.2 **[Computers and Information Science Education]**

## General Terms
Design, Evaluation

## Keywords
Education, Computer Science, Games Design, Imagine Cup

## 1. INTRODUCTION
As the number of gamers in US alone exceeds 155 million and has been increasing annually, the demand for more games in every genre and platform is also on the rise [8]. The rise of indie game startups to support this demand has prompted many educational institutions to open game design curricula to fulfill the needs for game designers in various disciplines. There are about 400 colleges in US that offer programs ranging from gaming courses to B.S/M.S./minor degrees and certificates [7]. The programs and corresponding curricula among colleges vary based on unique needs from the local gaming industry and/or the availability of resources. At University of Houston (UH), we offer four gaming courses in the computer science department to educate and train our students and guide them to pursue careers either in the traditional gaming industry or in the startup indie gaming industry.

Since UH only offers four game design related courses, it is necessary to design the curricula to be highly effective in training our students to become proficient entry-level game developers. For this reason, we design a multidisciplinary, multifaceted approach to improve our students' expertise and performance in game design and development.

Previously, Wolz et al. [21] introduced a curriculum where the students from various majors were taught game design by guest lecturers with multidisciplinary backgrounds for two semesters and were then required to produce individual games. While they selected the faculty members within their own institution as the guest lecturers, we invited most of our guest lecturers from the local gaming industry and other institutions except for guest lecturers in the business and entrepreneurship program. We placed the exception for this particular field since our institution has a nationally top-ranked entrepreneurship program with experienced entrepreneurs as faculty members. In addition, their multidisciplinary fields did not include the business and entrepreneurship as a part of their curriculum. We included this field in our curriculum since it can potentially benefit our students if they decide to pursue indie game startups. We also required our students to work on team projects as done by Bidarra et al. [3]. In the early years of our program, like Settle et al. [18], we required our students to focus on both individual and team projects. However, we later removed the individual projects from our curriculum to allow our students additional time to concentrate on their team projects. Bidarra et al. [3] permitted teams to have a large number of students but we limited the number to improve team logistics; we find that this leads to a more effective team game production process.

In order to assess the effectiveness of our approach, we decided to utilize our successes in national and/or international collegiate game design competitions as a primary parameter. We chose the Microsoft Imagine Cup to serve this purpose since it is a well-known student competition where students compete in both national and international settings. While Imagine Cup has been utilized as a foundation for computer science software capstone projects in the past [15], it has never been utilized as the tool to assess the effectiveness of game design programs before. For programs such as ours that offer a limited number of courses rather than a degree, it is difficult to find means to compare program quality with programs offering degrees by utilizing conventional methods – human and material resources [17]. The competition


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provides opportunities for student teams from different game design programs at universities to compete head-on and demonstrate the strength of their program.

# 2. OUR METHODOLOGY

To maximize the effectiveness of our game design and development, we implement various mechanisms such as a unique course format, multidisciplinary coursework, one-on-one support, grading policies and assessments that can best serve our purpose.

## 2.1 Course Format

We design our courses as team-project oriented courses where qualified computer science students form teams and design a game in two semesters.

### *2.1.1 Qualification*

Since our courses are listed as part of the computer science program, only computer science students are permitted to enroll them. For this reason, the courses are designed toward accommodating computer science students interested in learning about game development. However, we also permit computer technology, computer engineering or other major students with proficient programming skills to enroll.

Further, we also require enrolled students to be juniors, seniors or M.S./Ph.D. students. By allowing only qualified students to register, we ensure that they have sufficient computer science and programming skills to design their game – especially the core game engine. Another reason for not permitting freshmen and sophomores is to ensure that our courses do not get demoted to elementary programming courses. In the first few years of the program, lower level students (freshmen and sophomores) were able to register for the courses. Aside from obvious deficiencies in computer science and programming skills, they caused several problems in regard to work ethics, discipline and management skills. Consequently, they had a difficult time both in designing their own individual game and making reasonable contributions to their team game. For these reasons, we no longer permit the freshmen or sophomores in our classes.

### *2.1.2 Game Development Tools*

Prior to 2012, we chose Microsoft XNA Game Studio as the primary game development tool for our students. The XNA is a programming environment Microsoft introduced to the public in 2006 [6] that "allows you to use Visual Studio to create games for Windows Phone, Xbox 360, and Windows" [13]. At the time, we selected the XNA because of its three advantages over other tools: (1) Relative ease of programming using Microsoft Visual C#, (2) shorter coding length (C# over C++) and time to create a game, and (3) capability to create cross-platform games for a PC, console (Microsoft Xbox 360), and mobile device (Microsoft Windows Phone/Zune Player). Although it was a relatively simple tool to design a game in the past, it still required our students to create and write the core game engine. Therefore, our students had to invest a significant portion of their total development time in producing a functional core engine alone. In 2013, we gradually transitioned away from XNA since Microsoft announced it was ending its support. We permitted our students to develop their games using either XNA or Unity Studio. Unity is a GUI-based application programming interface (API) that allows game developers easily create 2D/3D games in multiplatform settings [19]. Starting in 2014, we recommended they utilize Unity as the primary tool to develop their games. The major reason for choosing Unity was its multi-platform support. Unlike XNA that only allowed our students to produce their games for Microsoft-specific platforms, Unity supports most consumer platforms including Microsoft, iOS and Android.

### *2.1.3 Individual and Team Projects*

In the first two years of our program, we required students to work on an individual game for two months. Our objective was to allow them to learn and experience the nature of the game design process and understand the fundamentals that every role required to produce a game. Afterward, we required them to form a team and produce a team-based game for the remainder of the course. However, we found that the difference between students entering the team project after completing their individual projects first or immediately starting the team project without first working on the individual projects was negligible. We also found that the students preferred to start the team project immediately so that they have more time to focus on developing their team game. The apparent benefits of starting with the individual project first were mostly covered in the team project as the students were required to understand roles and responsibilities and appoint themselves to the roles that were needed for their projects. Finally, we limited the number of team members to 4. As the size of the team increases, the workload it can handle increases. However, the size increase also contributes in increased logistical problems that potentially slow development processes when the number exceeds between 4 and 6. Furthermore, since Microsoft Imagine Cup competitions capped the maximum number of team members to 4, we adopted this rule as well.

## 2.2 Multidisciplinary Coursework

A successful game requires collaboration among a team of specialists from diverse disciplines such as computer science, art and animation, design, storytelling, audio and music, business and entrepreneurship, and legal. We aimed for our students to go beyond the traditional role of computer scientists in game development, which has been limited to developing a core game engine, artificial intelligence, network, and user interface (UI). We exposed them to the other aspects of developing a successful game which draws knowledge from the above disciplines. This required us teaching fundamentals from these disciplines so that our students can gain solid foundations that they can apply to develop successful games. In our program, we put a particular emphasis on the following disciplines: art and animation, design and production, and business and entrepreneurship.

### *2.2.1 Art and Animation*

We cover fundamentals of game art concept and animation design as well as teaching skills in modeling, lighting, motion, and rigging using Autodesk Maya while learning how to tell a game story using the art assets. We require our students to create game-specific environments – including landscapes, terrains, objects, characters and structures. Finally, we cover advanced concepts in designing and producing computer-generated art and animation for the gaming environment.

### *2.2.2 Design and Production*

The game design covers the creation of a blueprint for the game – developing game concepts and conveying these ideas to the rest of the team in a game design document (GDD) to turn the ideas into reality [16][14]. The role includes designing overall gameplays, user interface and user experience (UI/UX), and game levels including the world and environments, characters, and audio. We teach our students the process through the practice of research, critical analysis, brainstorming, and improvisation techniques to create ideas for an entertaining game. The discipline is especially

important at the beginning of the project when the concept of the game is being established. On the other hand, game production covers various methods and techniques to complete the game project on time and budget without sacrificing the quality, number of features, and entertainment factors [4][14]. The discipline is important throughout the project. We cover these disciplines to ensure our students successfully design a well-conceived, fun game and complete it on schedule.

### *2.2.3 Business and Entrepreneurship*

For the past decade, there has been major rise in indie game developers and subsequent startups in the video game industry. To accommodate those who are interested in the entrepreneurship, we dedicate several lectures in teaching the fundamentals of entrepreneurship and designing the simplified business plan using the lean canvas and the lean startup approach.

We cover this field for those who are interested in creating indie game startups in the future and equip them with the necessary knowledge and experience by the time they graduate. Although our program does not have a degree program specialized in game development and entrepreneurship [10], we offer our students support to pursue entrepreneurship in the indie game industry. If, after completing our courses, students wish to be exposed to more entrepreneurship resources, we connect them to the resources and infrastructure available at UH to help launch student startups.

The lean startup approach towards new ventures emphasizes continuous learning, customer development, and iteration. To apply this approach towards their game, students are required to draft a lean canvas, which covers the basic elements of a business model. They must then identify potential customer personas and validate their assumptions regarding their customer, pricing, and go-to-market strategy. In addition to business model development, students are required to pitch their game during the semester – preparing a pitch forces the students think about their game from a business and entrepreneurial perspective, and to learn to communicate aspects of their game in a simple, succinct, and engaging fashion.

## 2.3 Support

We regard the human factor as the most important factor in the game design process; personnel with experience and expertise offer constant guidance and recommendations to our students as they focus on producing their games throughout the semesters. For them to maximize the efficiency of their process and succeed in completing their game, we make available various support mechanisms from mentors, guest lectures, and teaching assistants.

### *2.3.1 Weekly Mentoring*

In the early years of our game education, we learned that our students require consistent guidance throughout the semester outside the classroom setting as they work on their projects. Since 2009, we implemented a system where the instructor works as a mentor and meets with each individual team on a designated schedule at least an hour weekly.

At the beginning of the semester, the mentor takes a responsibility to guide and help them understand their constraints and try not to be overly ambitious about their games. Students without experience in game design always tend to be very ambitious in terms of the scenario, gameplay and/or number and scale of playable levels. The mentor first listens to the teams about their game development plan and assesses how many features and assets can be feasibly completed over the courses. The mentor then consults with the students and agrees on what essential game components they should prioritize and designate milestones accordingly. In the meantime, they categorize the rest as "nice-to-have" components and produce them if they have time left after completing "must-have" components.

After completing the planning and preparation stage (also known as the pre-production stage), the teams start developing the game and report their progress on various elements of the game such as the core game engine, assets and user interface (UI) to the mentor each week. The mentor assesses their progress and advises on how to improve quality without neglecting milestones/deadlines. The mentor suggests improving the gameplay by tweaking existing features or adding new features without causing major feature creep. Simultaneously, the mentor informs them to remove some features and/or the assets if they can potentially cause bottlenecks or if they are found to be too time consuming to complete. By providing regular feedback, the mentor guides the teams to improve their production efficiency to help guarantee the completion of the game with all anticipated features and assets included at the end of the semesters.

This out-of-class weekly meeting is valuable for the students since they can discuss the project with their mentor and ask questions, solicit inputs and/or provide comments.

### *2.3.2 Guest Lecturers*

Throughout the semesters, we invite several guest lecturers with experience and proven expertise in various disciplines related to game design, either from the local gaming industry or from other academic institutions offering the game education. They offer fundamental knowledge by discussing their experiences, industry news, and advanced topics related to their fields of expertise. For example, we invited several faculty members from Guildhall at Southern Methodist University (SMU), who imparted their expertise in topics such as the game level design and arts. All our guest lecturers are invited from outside UH except for the field related to business and entrepreneurship since UH has a well-established business school with one of the top-ranked entrepreneurship programs in the nation according to Princeton Review and Entrepreneur Magazine in 2015 [11].

### *2.3.3 Teaching Assistant*

In addition to having competent instructors and qualified lecturers, we are improving our student support by employing talented teaching assistants. For the past 6 years, we have made an effort to target our former game students who have received recognition at the national and/or world level.

Consequently, we have successfully recruited teaching assistants who have participated and ranked in the Microsoft Imagine Cup competitions. Below is the criteria to be qualified as teaching assistants in our courses in descending order:

1. Winners or finalists in US competition
2. Semi-finalists in World competition
3. Semi-finalists or honorable mentions in US competition

The teaching assistants with the above qualifications possess talent in the game design and project management skills thanks to their prior experiences in advancing to the US finals or US/World semifinals. They can offer information about their own game development experiences – both their successes and pitfalls – to ensure the students to work on their projects more effectively. In each year, our teaching assistants have successfully demonstrated their value in raising the quality of the games produced.

## 2.4 Grading Policies

The grade of each student is composed mainly of three items: homework assignments, a final presentation and two team duels. The first two items are trivial components that are widely utilized by most institutions in their game design courses. Unique to our program is a component called team duels: team duels increase the quality of the games produced.

### *2.4.1 Homework Assignments*

The homework assignments are designed to help students prepare and schedule their team projects. They include preparing basic game design documents (GDD) and game development schedules in the pre-production and production stages. Since preparing these components are essential in developing and releasing a game successfully, we include them as assignments.

### *2.4.2 Final Presentation*

At the end of the semester, each team is required to make a final presentation before a panel of judges whom we invite from the gaming industry and academia to provide feedback. The teams are required to present basic information about their games to the judges. After the presentation, they showcase their games and allow the judges to play them so that the judges can assess them based on multiple factors such as gameplay, entertainment value, usability, and production quality. At the end of the final presentation, the panel discusses each game and reaches a consensus on what grade should be awarded to the team. This grade is given to the team as a team grade. However, the team grade is one of two factors that determines individual grades. The second factor is their individual contributions to their team games throughout the semesters. This grading system allows each student to earn an individually deserving grade and prevents him/her to receive a high grade without making a meaningful contribution. As an example, we had some cases where everyone in a team received an 'A' grade while one member of the same team received a 'D' grade for the lack of contribution and effort.

### *2.4.3 Team Duels*

The ranking duel system is designed to control and enhance the development progress, quality of assets and fun factor of the game that each team develops. Throughout semesters, the teams are expected to work a reasonable amount of hours (e.g. a minimum of 10 hours per member per week) and demonstrate effort to produce their games with the highest quality possible. Progress and achievements are judged in two dueling sessions known as the 'Rank D duel' and 'Rank C duel'. After we replaced intermediate presentations with the duel system, we observed the number of students enrolling our courses dropped by about 20%. However, it also greatly contributed in improving the quality of the games produced.

At the beginning of the semester, we classify the teams as D-rank teams, equivalent to the teams having a 'D' as their final grade. In designated weeks in late September and early October, we host a 'Rank D duel' where two D-rank teams duel by demonstrating their game components such as the core game, levels, features, assets, fun factor, and project quality in the presentations and demonstrations. The winning team of the duel advances to C-rank equivalent to the team having 'C' as its final grade. The lost team remains in D-rank and must duel against other D-rank teams during the designated weeks until it wins and advances to C-rank. However, we only allow each team to participate in the duel once per each class. The team that already participated and lost the duel in one class must wait until the next class to duel against another D-rank team.

We held the 'Rank C duel' about a month afterward, in a manner similar to the 'Rank D duel'. The winning teams advance to B-rank equivalent to having 'B' as their final team grades. These team ranks are carried into the final presentation where we determine the final team grades. Only B-rank teams are eligible to receive 'A' as their team grades at the end of the final presentation.

## 2.5 Assessments of Our Game Program

One way to assess the quality of our game education is to frequently engage with guest lecturers and judges from the gaming industry and academia with gaming programs who are given opportunities to meet with our students and assess their games. They can determine the competency of our students as potential future game developers and the effectiveness of our education: their assessments contribute significantly in improving our program continuously.

In addition, since the beginning of our game program, we continuously sought a novel method to learn where our program stood in national and international realms. We decided to utilize outcomes from annual game design competitions such as Microsoft Imagine Cup competition to assess the quality of our education. We let our students submit their games both to US and World Imagine Cup competitions and compete against student developers from other game programs in US and/or world. We monitored the outcomes from these competitions in each year to confirm the quality of our program. Having persistent successes by our students from the competitions validated the effectiveness of our pedagogical approach.

# 3. OUTCOMES AND EVALUATION

Microsoft Imagine Cup is a premier national and international student technology competition designed to challenge students to build software or games [12]. In terms of the game design competition, unlike the software design competition, the Imagine Cup is only one of few available competitions specifically designed for college students to compete in game design at national and international stages. We have led our students to compete in the game design category since 2007.

In addition to utilizing competitions to validate the effectiveness of our approach, we also utilized them to motivate our students to excel in developing their games. Instead of regarding their works merely as classroom projects in an isolated university classroom setting, our students perceived themselves as part of teams developing their games to compete against peer student competitors from US and/or world. This factor and their desire to be recognized encouraged the large majority of the students competing in the competition to invest more hours and efforts to produce high-quality games. The small number of the students who did not compete invested far less hours in their team games than those who competed. We observed that the parity between these two groups, in regards to the invested time, were more than 3 times. Subsequently, the quality and the fun factor of every game produced by the teams competing in Imagine Cup were far superior to those who did not.

Second, we utilized the competition as means for our students to assess their projects in the national and international settings by comparing their games with competitors' games from other institutions. They assessed their games by comparing multiple components including the game quality and fun factor. With information about past winners' games Microsoft provided to the public, our students compared their games with the winners' and led them to continue improving their games.

We also chose to incorporate Imagine Cup competitions into our curriculum since they fit well with our academic calendar. The US competition is composed with two semi-finals – one in fall and another in spring – where Microsoft selects half of the total finalists in each semi-final. Those who were selected as the finalist in any of two semi-finals are invited to the final competition in April – the District of Columbia in 2010, Redmond (WA) in 2011 and 2012, San Jose (CA) in 2013, online (virtual) in 2014, and San Francisco (CA) in 2015. Since we offered our courses in fall and spring, the competitions fit well for our students to schedule their developmental cycles around it and compete. According to the semi-final rule, the teams that are not selected as finalists after fall semi-final can improve their games and submit again in the spring semi-final for another chance to be selected as finalists. Thus, the teams have two opportunities to be selected as finalists.

In the US Imagine Cup, we achieved the following successes:

1. 2010 – 27,000 participants / Total 10 finalists
   a. Number of finalists from our program: 2 (20%)
   b. Final ranking: 2nd and 3rd
2. 2011 – 74,000 participants / Total 12 finalists
   a. Number of finalists from our program: 4 (33%)
   b. Final ranking: 1st and 2nd (Mobile) and 3rd (PC/Xbox)
3. 2012 – 113,000 participants / Total 12 finalists
   a. Number of finalists from our program: 3 (25%)
   b. Final ranking: 3rd (Mobile) and 4th (PC/Xbox)
4. 2013 – Total 4 finalists
   a. Number of finalists from our program: 2 (50%)
   b. Final ranking: N/A (Only 1st place winner announced)
5. 2014 – Total 2 finalists
   a. Number of finalist from our program: 1 (50%)
   b. Final ranking: 1st (Figure 1)
6. 2015 – Total 4 finalists
   a. Number of finalist from our program: 1 (25%)
   b. Final ranking: N/A (Only 1st place winner announced)

**Figure 1. A gameplay screen of "Unnatural Selection", the 2014 US Imagine Cup winner and World Imagine Cup semi-finalist representing USA**

The teams from our program has dominated the competition since 2010, the first year that the US Imagine Cup competition started the game design category. The number of finalists (13), winnings (two-1st places, two-2nd places, three-3rd places and one-4th place), and number of consecutive years the teams from our program successfully advanced to the final (6 consecutive years) are unprecedented in the competition's history. Our accomplishments in 2011 are especially noteworthy in terms of a number of finalists and winners. Figure 2 shows some of finalists and a mentor at the 2011 US Imagine Cup final. To our knowledge, our best competitor had a total of 2 finalists and had their gaming teams advancing to the final for two consecutive years. These results clearly validate the effectiveness of our pedagogical approach in leading our students to be highly competitive against their peers from other institutions for 6 consecutive years.


**Figure 2. Some of US Imagine Cup finalists and mentors from our university attending the final**

We also participated in the World Imagine Cup competition. Until 2012, the participants had to submit their products to three competition rounds: 1, 2 and 3 (semi-final). Only four teams were selected as finalists after round 3 and competed in the World final. Starting in 2013, only the 1st place winners from each local competition were selected as the world semi-finalist teams and competed to be selected as finalists. The teams were not permitted to submit their games in both national and world competitions separately. Instead, the only way to compete in the world competition is to win the local final (US competition in our case). Below is the list of our successes in the world competition:

1. 2008 – 1 semi-finalist ranked in top 25
2. 2009 – 1 semi-finalist ranked in top 100
3. 2010 – 4 semi-finalists ranked in top 48
4. 2011 – 6 semi-finalists ranked in top 50
5. 2012 – 9 semi-finalists ranked in top 200
6. 2014 – Sole semi-finalist representing USA

The unprecedented number of semi-finalists from our program between 2008 and 2014 also successfully demonstrates the quality of our game program in the international setting.

When we combine the number of our students making achievements and receiving recognitions both in the US and world competitions between 2008 and 2015, it becomes clear that a large majority of our students successfully demonstrated their ability as competent student game developers. This validates the effectiveness of our pedagogical approach that led to our students' successes for 8 consecutive years. Our success stories were published in various media. Multiple news channels from several local TV stations interviewed us every year between 2010 and 2014 – ABC in 2010 [1] and 2012 [2], CBS in 2011 [5], CW in 2013 [9] and FOX in 2014 [20].

Finally, Microsoft World Imagine Cup organizers recognized one of the authors, Yun, as one of the most successful game design educators and asked him to join judging teams to judge submitted games from all over the world. He assessed the quality of 15 games and recognized that the quality the top-tier games (two games he judged advanced to the final) were on par with the quality of the games that our students produced. His assessment was proven to be valid as 6 teams from our program advanced to the semi-final in 2011 competition.

## 4. CONCLUSIONS AND DISCUSSIONS

Our multidisciplinary and multifaceted approach successfully enhanced the quality our game design program. Our students attained fundamental knowledge and skills in multiple disciplines by the instructors and guest lecturers from the local game industry and other institutions with their own game design program. Utilizing these knowledge and skills to design games benefited our students as they offer insights on how the game design process is perceived and handled uniquely by different disciplines. This led to a clear division of roles and responsibilities among the team members from an early stage of the development process. Each team also recognized its capabilities/constraints and designed the game to a more realistic degree which resulted in successful completion of its game according to plans. Even after the completion of the courses, in collaboration with the business and entrepreneurship programs at UH, we offer the continual education, training and support from students who express interest in pursuing their own indie game startups. Our multifaceted approach also improved the strength of our courses. In regularly scheduled weekly meetings outside the classes, the mentor provided guidance, mentoring and recommendations to each team. He helped the students expedite their development by mitigating bottlenecks while directing them to choose and focus on essential features and improve the quality of the features and assets.

Teaching assistants who previously took our courses and won national and/or international recognitions significantly contributed in enhancing the students' game design skills and improving the quality of their games. The teaching assistants were greatly effective in assisting the students in each production phase of their projects by utilizing their own previous game design experiences. Further, using their own previous projects as standards, the teaching assistants contributed in helping the students to improve the quality and fun factors of the games.

The ranking duel system contributed significantly in improving the quality of games developed in our courses as it promoted competitiveness among the teams. Although the grade was the primary reason for our students becoming competitive, the nature of the duel and expectation to win pushed them to be further competitive and, consequently, promoted the major improvements in every game that was developed in our courses.

The effectiveness of our multidisciplinary and multifaceted approach was successfully validated in Microsoft US and World Imagine Cup competitions. In US competitions, our students advanced to the final for 6 consecutive years since 2010 and gained multiple records and winnings. In World competitions, they advanced to the semifinals 6 out of 8 years since 2009. Both records demonstrate the effectiveness of our unique approach that helped to educate our students and, consequently, led them to produce top-tier national/international games and achieve unprecedented records in Imagine Cup history.

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