Université de Montréal

A Game Theoretical Model for a Collaborative E-learning Platform on Privacy Awareness

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Mémoire présenté en vue de l’obtention du grade de Maître ès sciences (M.Sc.)

en informatique

Avril 2020

Université de Montréal

Département d’Informatique et de Recherche Opérationnelle, Faculté des Arts et des Sciences

Ce mémoire intitulé

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Résumé

De nos jours, avec l'utilisation croissante des technologies numériques, l'éducation à la préservation de la vie privée joue un rôle important en particulier pour les adolescents. Bien que plusieurs plateformes d'apprentissage en ligne à la sensibilisation à la vie privée aient été mises en œuvre, elles sont généralement basées sur des techniques traditionnelles d'apprentissage. Plus particulièrement, ces plateformes ne permettent pas aux étudiants de coopérer et de partager leurs connaissances afin d'améliorer leur apprentissage ensemble. En d'autres termes, elles manquent d'interactions élève-élève.

Des recherches récentes sur les méthodes d'apprentissage montrent que la collaboration entre élèves peut entraîner de meilleurs résultats d'apprentissage par rapport à d'autres approches. De plus, le domaine de la vie privée étant fortement lié à la vie sociale des adolescents, il est préférable de fournir un environnement d'apprentissage collaboratif où l'on peut enseigner la préservation de la vie privée, et en même temps, permettre aux étudiants de partager leurs connaissances. Il serait souhaitable que ces derniers puissent interagir les uns avec les autres, résoudre des questionnaires en collaboration et discuter de problèmes et de situations de confidentialité.

À cet effet, ce travail propose « Teens-online », une plateforme d'apprentissage en ligne collaborative pour la sensibilisation à la vie privée. Le programme d'études fourni dans cette plateforme est basé sur le *Référentiel de formation des élèves à la protection des données personnelles*. De plus, la plateforme proposée est équipée d'un mécanisme d'appariement de partenaires basé sur la théorie des jeux. Ce mécanisme garantit un appariement élève-élève stable en fonction des besoins de l'élève (comportement et / ou connaissances). Ainsi, des avantages mutuels seront obtenus en minimisant les chances de coopérer avec des pairs incompatibles.

Les résultats expérimentaux montrent que l'utilité moyenne obtenue en appliquant l'algorithme proposé est beaucoup plus élevée que celle obtenue en utilisant d'autres mécanismes d'appariement. Les résultats suggèrent qu'en adoptant l'approche proposée, chaque élève peut être jumelé avec des partenaires optimaux, qui obtiennent également en retour des résultats d'apprentissage plus élevés.

Mots-clés : Apprentissage collaboratif, Théorie des jeux, Éducation à la préservation de la vie privée, Apprentissage en ligne, Système de tutorat, Problème de mariages stables.

Abstract

Nowadays, with the increasing use of digital technologies, especially for teenagers, privacy education plays an important role in their lives. While several e-learning platforms for privacy awareness training have been implemented, they are typically based on traditional learning techniques. In particular, these platforms do not allow students to cooperate and share knowledge with each other in order to achieve mutual benefits and improve learning outcomes. In other words, they lack student-student interaction. Recent research on learning methods shows that the collaboration among students can result in better learning outcomes compared to other learning approaches.

Motivated by the above-mentioned facts, and since privacy domain is strongly linked to the social lives of teens, there is a pressing need for providing a collaborative learning platform for teaching privacy, and at the same time, allows students to share knowledge, interact with each other, solve quizzes collaboratively, and discuss privacy issues and situations.

For this purpose, this work proposes “Teens-online”, a collaborative e-learning platform for privacy awareness. The curriculum provided in this platform is based on the *Personal Data Protection Competency Framework for School Students*.

Moreover, the proposed platform is equipped with a partner-matching mechanism based on matching game theory. This mechanism guarantees a stable student-student matching according to a student's need (behavior and/or knowledge). Thus, mutual benefits will be attained by minimizing the chances of cooperating with incompatible students.

Experimental results show that the average learning-related utility obtained by applying the proposed partner-matching algorithm is much higher than the average utility obtained using other matching mechanisms. The results also suggest that by adopting the proposed approach, each student can be paired with their optimal partners, which in turn helps them reach their highest learning outcomes.

Keywords : Collaborative learning, Game theory, Privacy education, E-learning, Stable matching problem.

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List of abbreviations

CSCL	Computer-Supported Collaborative Learning
CL	Collaborative Learning
CPS	Collaborative Problem-Solving
SMP	Stable Marriage Problem
H-A	Human-to-Agent collaboration
H-H	Human-to-Human collaboration
GTPS	Game Theory-Based Partner Selection algorithm
PDPCFSS	Personal Data Protection Competency Framework for School Students
PCM	Preference-based homogeneous Clustering Method
CCM	Characteristics-based homogeneous Clustering Method
RM	Random-based Matching

To my love, Dikran, for his endless love, support, and encouragement

and our sons Jad Joseph and Roy, who have been a source of inspiration....

Acknowledgments

I would like to thank my wonderful supervisor, Professor Esma Aïmeur, for her understanding, continuous guidance, great supervision, and full support. I was lucky to be supervised by such a professional, inspirational, and caring advisor. Thanks for believing in my potential and letting me explore the field of Intelligent Tutoring System. Without your guidance and persistent support, this dissertation would not have been possible.

I would like to thank, with an abundance of gratitude, Dr. Adel Abusitta for the continuous support of my study and research, for his patience, motivation, enthusiasm, and immense knowledge.

Moreover, I would like to thank the jury members, Professor Philippe Langlais and Professor Emma Frejinger, for sparing their precious time in order to review and evaluate my thesis.

I thank my fellow labmates in the Artificial Intelligence and Cyber Security Group, for the stimulating discussions and for all the fun we have had in the last two years. I would particularly like to thank my dear colleague and friend Ghada, for teaching me several tips while I write my articles and my research work. Thanks to Rim and Sabrine for being my awesome desk-mates during the last year. Thanks to Hamed and Camille for being my partners during the security course and thank you for those nights of work in the lab. Thanks to Ayman for explaining cyber-security aspects and helping me on many occasions. Thanks to Caroline for the time we spent together and for correcting my mistakes. I would like to thank Mme Céline Bégin for her kindness and her efficiency as well as the whole UdeM administration team.

I would also like to warmly thank Dr. Antonio Tavares, who had encouraged me to take this step. Thank you for being more than a brother with your advice and support, and thank you for giving me the opportunity to work as your teaching assistant, which was a great and constructive experience.

Last but not the least, I would like to thank my family, my parents, and my brothers for all the support they gave me during this adventure.

Chapter 1 – Introduction

In this chapter, we present the context of our research work, describe the problems addressed in this thesis, identify the corresponding research questions, and finally indicate the objectives of our research work. The background and related work will be presented in Chapter 2.

1.1. Problem Definition and Motivation

In an era where information and communication technology (ICT) is advancing at an unprecedented rate, privacy issues take up a lot of space in our cyber life. This is due to the fact that peoples' personal information has become a valuable commodity sought by many companies (Aïmeur *et al.*, 2006). Moreover, it has become significantly more difficult for individuals to detect who is processing their data and for what purpose.

Privacy issues are a particular threat for young people, as they spend most of their time browsing websites and social networking sites online. Stephanidis, Salvendy *et al*. (2019) noted that privacy is one of the biggest challenges in our everyday lives when interacting with technology-augmented environments, after ethics and security. Greer (2016) also considered the danger of using the virtual word without ethics as a moral panic that threatens young people. Aïmeur and Hage (2010) have discussed the challenges of the preservation of e-learning privacy, as they have proposed a set of protocols in order to preserve the learner's privacy (Aïmeur *et al*., 2008). Thus, many risks related to privacy can occur, from hacking and e-mail scamming to cyberbullying, tracking, child luring, and, more recently, online suicide challenges (i.e. blue whale challenge). According to Statistics Canada[1], the number of child luring cases through the Internet in adult criminal court increased exponentially. In 2018, they recorded 1,272 cases. The greater accessibility of the Internet to youth, compared to other population groups, has increased their risk of victimization.

This indicates an urgent need for privacy education to help teenagers avoid many online risks in order to enjoy the benefits of online services while also protecting their privacy. In fact, privacy

[1] Statistics Canada 2018. Table 35-10-0001-01 Police-reported cybercrime, by cyber-related violation, Canada (selected police services) accessed 20/07/2019

competence is officially recognized in many countries, as well as Quebec, as a part of numerical competency[2].

Many classroom materials and curricula on online privacy have been developed recently (e.g. *Common Sense Media*, *NetSafe* and (Egelman et al., 2016, p. https://teachingprivacy.org/; Fortin, 2019). All of them are of high quality and considered as massive projects. However, the problem with these existing courses is that they are designed to be learning tools used by educators in the classroom to demonstrate what happens to personal information online, and the potential risks of sharing it. Therefore, these courses are closer to educational materials than tutoring systems. Also, they use traditional approaches in education, which are basically designed for individuals. In other words, they are single-user learning environments and do not provide enough support for group collaboration. Although most e-learning platforms enable learning to be done by studying at home or at work using computers and courses provided on the Internet, they lack student-student interaction. This leads to feelings of isolation as they are disconnected from their peers, which in turn hinders the e-learning experience (Thanh *et al*., 2019).

Many studies have shown that collaborative students are more likely to improve their skills in multiple subjects, including mathematics and science. Smith and MacGregor(1992) confirmed that in a collaborative learning environment, members are challenged on two levels, socially and emotionally. This approach allows students to interact with each other and learn how to express, negotiate, and defend their ideas in order to achieve mutual benefits. They also have the chance to learn from different backgrounds (Aïmeur *et al*., 2005). In so doing, the learner can create his/her own learning framework and not depend on the course's context alone.

Recently, Computer-supported Collaborative Learning (CSCL) has become one of the essential pedagogical techniques (Halavais, 2016), due to many benefits that can be achieved using collaborative learning CL, such as obtaining in-depth knowledge, motivating and improving students engagement, and even developing learning results (Mani & Pasupathi, 2018; Petrunich-

[2] Digital Competency Framework 2019: http://www.education.gouv.qc.ca/en/references/publications/results/detail/article/digital-competency-framework-1/ accessed 22/01/2020

Rutherford & Daniel, 2019). Greer et al. (2018) focuses on the importance of reinforcing a collaborative environment for discussion, sharing ideas, thinking and problem solving, and shows how collaborative learning and the interaction with peers can motivate students to engage more in learning activities (Orji, Greer, *et al*., 2019).

There are many significant studies in the field of collaborative learning (Goel & Joyner, 2016), and collaborative problem solving (Stewart & D'Mello, 2018). However, the shortcomings of these studies, as well as one of the critical problems in the collaborative environment, is the lack of mechanisms for selecting the optimal partner(s) that helps us reach the best learning outcomes. In fact, working with an incompatible person may inhibit group functioning and individual learning, which in turn will negatively affect the education process. Some researchers in the area of CL confirm that inadequate peer matching has been the main reason for many unsuccessful CL applications (Cruz & Isotani, 2014). Therefore, partner selection is an important and fundamental process and should not be done randomly.

Partner selection or group formation is an important and complex step to design effective collaborative learning activities. In a number of recent research studies, many of the students' individual characteristics and preferences were used as grouping criteria, such as personality (Jadin *et al*., 2013), learning styles (Mehennaoui *et al*., 2014), topic-specific knowledge level (V. D. Yannibelli *et al*., 2016), demographic traits (Ounnas *et al*., 2008) (Makransky *et al*., 2019), communication skills (Moreno *et al*., 2012), and topic preferences (Spoelstra *et al*., 2013). However, each study adopted only an individual characteristic or a small set of factors. This may result in poorly formed groups in terms of other dimensions, such as personal behavior, expertise, and knowledge. Moreover, they do not achieve a stable match among students; thus, it does not lead to reciprocal satisfaction for the group as a whole.

All the above problems have led to the rise of the following research questions that we will thoroughly address throughout this thesis:

- How do we build and design a tutoring system that fits the learning style of teens in order to teach them privacy, online ethics, and how to avoid all risks related to privacy? Also how do we design courses with a well-structured curriculum?

- How do we design a student-student interaction, in order to prevent feelings of isolation during the online courses and achieve collaboration among students?
- How do we achieve good partner selection in order to fit each student's preferences in terms of knowledge and interactions?
- How do we prevent the problems caused by working with inappropriate partners?

1.2. Research Objectives

The purpose of this thesis is to providing a collaborative e-learning platform to equip teenagers with the knowledge necessary to navigate the digital world, enjoy the benefits of being online, and participate in digital technology while protecting their privacy. More specifically, the objectives of this thesis are:

- Propose a well-structured curriculum that covers the necessary concepts of privacy, such as online ethics, security, economical and technical aspects, and shedding light on the risks associated with the online world. Then, design courses in a way that corresponds to teenagers' learning style, such as videos and quizzes that expose real situations.
- Design an e-learning platform with courses divided into modules and smaller topics and use modern learning theories such as microlearning and gamification.
- Provide a collaborative environment that achieves student-student interaction in order to enable students to share ideas while learning.
- Propose a stable matching mechanism that helps to select the optimal partner for each student according to their knowledge profiles.
- Improve the selection of partners and also the interaction between students in order to prevent problems caused by working with inappropriate partners.

1.3. Main Contributions and their Originality

Motivated by the importance of collaboration in an e-learning environment, as well as the importance of privacy awareness for teenagers, we propose "Teens-Online"[3], a collaborative

[3] http://www-ens.iro.umontreal.ca/~yusririt/teensonline/

e-learning platform for privacy awareness. The proposed platform is designed for teenagers between the ages of 13-18 and will allow the student to learn and to benefit from his/her partners by exchanging knowledge. This platform proposes a Game Theory-based Partner Selection algorithm (GTPS) in order to obtain a stable match between students by choosing the optimal partner(s) for each student according to his/her preferences. The proposed model guarantees stability in the sense that no student has an incentive to leave his/her current coalition (partner) and join another one.

For the selection criteria, we propose using two categories of characteristics or factors, classified by Thanh *et al*. (2019), which will influence group formation. The first category is *academic factors*, represented by *knowledge qualities*, and consists of topic-specific knowledge levels of the students in order to increase the benefits of collaboration by pairing students who can support each other based on complementary competences. The knowledge profile is initialized first by a pre-test and changed adaptively when a student completes the courses and quizzes. The second category is *socio-psychological factors,* represented by *behavior factors,* and consists of personality traits that are considered essential to improve collaborative work and help students succeed. The behavior history for each student is taken from partners' evaluations.

Motivated by the importance of persuasive strategies in encouraging students to successfully change behaviors, the proposed platform adopts gamification elements, which are a type of Persuasive Technology (Chalco *et al*., 2015) that leverage the persuasive power of games to cause behavior changes in people (Orji, Greer, *et al*., 2019). The proposed courses in the platform, as well as videos and quizzes, were all designed based on the *Personal Data Protection Competency Framework for School Students* (PDPCFSS)[4]. This framework was proposed by the Privacy Commissioner of Canada to the Council of Ministers of Education[5] after the 38th International

[4] International Digital Education Working Group (2016). Personal Data Protection Competency Framework for School Students. 38th *International Data Protection and Privacy Commissioners' conference* ICDPPC. accessed 22/01/2020

[5] Joint letter to the council of ministers of education: https://www.priv.gc.ca/en/opc-news/news-and-announcements/2017/let_171103/ accessed 22/01/2020

Conference of Data Protection and Privacy Commissioners, as a solution for the many risks associated with connecting to the Internet.

This work consists of the following contributions:

- Design and implement a collaborative e-learning platform for privacy awareness that enables teenagers to acquire the necessary knowledge on privacy and share ideas among themselves (Yusri et al., 2020b).
- Propose a partner-matching mechanism based on matching game theory, more specifically on stable marriage algorithm, that guarantees a stable match among students (Yusri et al., 2020a).
- Integrate the history of partners' interactions (i.e. partners' knowledge and behavior) into the proposed matching algorithm in order to allow students to improve their selections and learn from their experiences, as well as from their colleagues' experiences.

1.4. Thesis Structure

In Chapter 2 we discuss the background and literature review. The proposed collaborative e-learning platform on privacy awareness is presented in Chapter 3. An experimental evaluation is presented in Chapter 4. Finally, Chapter 5 concludes this research and discusses future work.

Chapter 2 – Background and Literature Review

In this chapter, we discuss recent works that have been done in the areas connected to this thesis.

2.1. Privacy Education

Privacy education is not a new topic, and many online courses have been designed recently to raise awareness of privacy issues among children and young adults. For example, Egelman *et al.* (2016) proposed "The Teaching Privacy Curriculum", which was designed for high school students and consists of ten principles that describe how online privacy education works both technically and socially, along with the potential negative consequences of over-sharing. Based on this curriculum, the International Computer Science Institute (ICSI) and the University of California-Berkeley developed the "*teachingprivacy.org*" website that includes text, videos, and external resources. Similarly, the *NetSafe Utah project*[6], funded by the Sexual Exploitation of Children Prevention, is a website that includes online resources based on questions and answers, animation videos, and games, designed to help teachers and parents in terms of *tech privacy*.

The Common-Sense Media's Digital Citizenship Curriculum[7], is considered an important resource for parents and educators in elementary, middle, and high school. It includes a variety of topics and lesson plans about protecting a student's privacy on social media and how to make smart choices online. At the college level, there is the *"cyberself.ca"* project[8], which was developed and supported by "*Fédération des cégeps*". This project addresses the following fours topics: cyberbullying, offline meeting, cyber reputation, and identity theft. It also spotlights the risks associated with each of these problems and how to prevent these situations. Similarly, Santa Clara University has supported a new project called "*Your Privacy Online*"[9], which addresses privacy issues from a law perspective.

[6] www.netsafeutah.org/teens/index.html consulted on 20/07/2019

[7] Common Sense Media. K-12 digital citizenship curriculum. https://www.commonsensemedia.org/educators/curriculum. accessed 20/01/2020

[8] CyberSelf.ca https://monimageweb.com accessed 20/01/2020

[9] Markkula Center for Applied Ethics, Santa Clara University. Your privacy online. https://www.scu.edu/ethics/privacy/ accessed 20/01/2020

One of the large projects funded by the Privacy Commissioner of Canada is "*Media Smarts"*[10]. This project offers educational resources, including classroom lesson plans and framework sheets, as tools to educators, which can help children and teens protect their privacy online. The *NetSmartz* project[11], supported by the National Center for Missing & Exploited Children, is also considered an important project that supports educational resources for both students and teachers.

As an empirical study, Wang *et al*. (2017) designed a quiz-based privacy learning tool. They collected the quizzes' answers through Crowdsourcing and built their platform by leveraging the crowd's knowledge and experiences. The study shows that the crowd can offer high quality material to learn privacy, since questions are collected from users from different backgrounds and experiences.

In the Intelligent Tutoring Systems (ITS) field, Mahdi *et al*. (2016) provided an ITS for teaching information security to computer science students. AbuEl-Reesh and Abu-Naser (2018) created CCAITS for learning cryptography algorithms. However, there was no ITS developed for privacy education.

Most of the above-mentioned projects are huge and useful. Also, the frameworks proposed in these projects provided good materials for improving learning outcomes. In fact, we have used some of them as references in this work. However, the main disadvantage of these projects is that they are not specifically designed for students, since they provide only learning tools or classroom lesson plans that can be used by teachers to help them teach privacy concepts in their classrooms. They are closer to educational materials than tutoring systems. In other words, these projects are static websites that contain pedagogical materials. Moreover, most of these projects do not have student profiles, resulting in students going through multiple topics without considering the prerequisites of these topics (all of the courses are open). Also, the course plans

[10] MediaSmarts, 2013. http://mediasmarts.ca/. accessed 25/01/2020

[11] National Center for Missing & Exploited Children. Netsmartz workshop: Teaching materials. https://www.missingkids.org/NetSmartz accessed 20/01/2020

provided in these projects are not designed to guide students according to an ontology. This, in turn, makes them feel lost and bored.

In contrast, the proposed platform enables a student to go through many topics that depend on each other based on the adopted framework (PDPCFSS). The proposed platform also applies a “microlearning” method that allows us to divide each topic into smaller sub-topics. This, in turn, allows us to guarantee that a student cannot start a new topic without completing its prerequisite and passing a short quiz.

Unlike other single-user e-learning platforms, the proposed platform provides student-student interaction. This enables each student to collaborate, exchange knowledge and ideas, and solve assignments with his/her partner(s). Moreover, students can discuss privacy issues amongst themselves via the proposed private/public discussion forum. This means that a student can learn while at the same time exchanging knowledge and experience, collaborate with partners, and compete with others, thus increasing the student’s levels of interest and engagement.

2.2. Collaborative Learning

Collaborative Learning (CL) is a pedagogical approach to teaching and learning that involves groups of learners working together in order to solve a problem or complete a task (Laal & Ghodsi, 2012).

The collaborative learning approach has been adopted by many e-learning platforms. For example, Aïmeur and Frasson (1996) had an early initiative by proposing a pedagogical agent as a companion who simulates a peer interaction in the learning process, where the learner can co-operate with a co-learner who has similar objectives and knowledge levels.

Monahan *et al*. (2008) developed CLEV-R, a collaborative learning environment with virtual reality. They presented the collaborative environment as a 3D classroom by simulating the real classroom. In this environment, students can see each other as 3D images and can therefore communicate and participate with each other in real-time.

Similarly, Franceschi *et al*. (2009) proved that group learning can be supported by taking advantage of virtual world technologies that allow students to share a visual space as a 3D environment, and meet and interact via avatars. This gives the sense of group presence and supports the collaborative approach.

The two works mentioned above (Monahan *et al*., 2008) (Franceschi *et al*., 2009) represent collaborative learning by sharing in the quasi-realism of a 3D classroom. These works focus on the physical presence of students and how to technically mimic a real classroom environment; however, they do not allow students to collaborate as a group while working on assignments.

The idea of collaborative quiz is not new. Quinn and Eckerson (2010) highlighted the benefits of collaborative quizzes in their work. The idea was born when a teacher, Mr. Quinn, tried to respond to students complaining about an English reading quiz, and they asked to put the quiz off until the next day. Mr. Quinn suggested that they to do the quiz together and return one copy for each group. He was surprised by the unexpected high quality of the discussion that developed while the students worked together to gain consensus on their answers.

From a psychological perspective, Petrunich-Rutherford and Daniel (2019) recently demonstrated that collaborative quizzes help students get in-depth knowledge and a better understanding of course material. In their study, they divided students into two sections. In the first section, the students solved quizzes collaboratively. In the second section, the students solved their quizzes individually. By comparing students' performance of both sections, they found that the course grades of the collaborative students (section 1) had increased. Section 1 also had higher overall course grades, whereas the grades of the non-cooperative students (section 2) had decreased. In addition, collaborative quizzes motivated students to better prepare the material in advance. This study has been done for ordinary classrooms and does not provide results for e-learning environments.

In recent years there have been a number of significant studies in the field of collaborative learning, such as (Goel & Joyner, 2016), where they adopted CL as a part of their project by forming small “study groups” in the course. Stewart and D’Mello (2018) adopted the Collaborative Problem-solving approach (CPS) in the domain of computer programming. Rosen (2015) provided a CPS skill assessment by comparing H-A and H-H collaboration. Adeniran *et al*. (2019) presented a model that evaluated online group collaboration by characterizing textual discussion.

Mora *et al*. (2020) proposed a learning project based on a collaborative working model. This model used a peer review assessment methodology implemented in a web-based learning platform that enabled students to peer review their classmates' works by writing comments, suggesting improvements, and assessing final assignments. This study found that the final grade of the students exceeded what any individual student was able to produce. Thus, collaborating in peer review increases the students' motivation and promotes active learning.

The shortcoming of the above-mentioned works and one of the critical problems in the collaborative environment is the lack of mechanisms for selecting the optimal partner(s). To address this problem, this thesis proposes a Game Theory-based Partner Selection mechanism (GTPS) using a stable matching algorithm (Gale & Shapley, 2013).

2.3. Game Theory

The matching game algorithm has been used for various purposes, such as trip-vehicle assignment in ride-sharing (Bei & Zhang, 2018), matching with user arrival distribution drift (Zhou *et al*., 2019), and for General Video Game Playing (Bei & Zhang, 2018). Hosseini *et al*. (2015) formulated a matching algorithm with dynamic ordinal preferences and Sintov *et al*. (2016) extended a game-based platform for teaching AI. More specifically, the stable marriage algorithm or Stable Marriage Problem (SMP) (Gale & Shapley, 2013) has been used for the purpose of pairing two sets of elements, such as doctors to hospitals (Nguyen & Vohra, 2018) when a hospital has a fixed budget (Kawase & Iwasaki, 2018), students to projects (Modi *et al*., 2018), or teachers to schools (Cechlárová *et al*., 2016).

In our platform, the purpose of using this algorithm is to guarantee a stable match between students and their partners.

2.4. Peer Recommendation

Early research in the peer recommendation domain was performed by Greer et al. (1998). They proposed PHeLpS, the Peer Help System, which allows students to find a peer helper and facilitate direct communication between them. To select appropriate helpers, the student models are analyzed based on evaluations of knowledge and willingness to provide help and competency.

These analysis methods are calculated as a score for each student and used by the system to choose appropriate peers when required. Then, a subsequent system I-Help (Bull *et al*., 2001) provides two I-Help discussion components: private and public discussions. In order to recommend a suitable peer for the private discussion, the system provides an appropriate match using the student modelling, which has the advantage of existing peer networks as a learning resource in just-in-time requests for help in an online environment. Later, PHelpS and I-Help were used as the seed of other systems that were influenced by them (Vassileva *et al*., 2016).

Other researchers studied different factors used to effect peer recommendations, such as knowledge state, availability and preferences (Khosravi, 2017), demographics, qualification, and interests (Prabhakar et al., 2017). Makransky et al. (2019) studied the gender matching effect in learning with pedagogical agents. Alfonseca et al. (2006) and Mehennaoui et al. (2014) used learning styles to group students who prefer similar styles in order to adapt the content for groups. Isotani et al. (2009) used an ontological approach to form groups according to individual goals. V. D. Yannibelli et al. (2016) considered the understanding and interest levels of students to build learning teams. . In the field of CSCL, Dillenbourg and Jermann (2007) design ArgueGraph, as a conflict-resolution script, in which they form pairs of students with opposite opinions, in order to increase the difficulty of consensus building, and hence more justifications and more negotiation are required. On the contrary, Aronson (1978) provides JIGSAW scripts that pair students with different but complementary knowledge in order to increase the efforts that group members have to engage into and reach a shared solution.

Olakanmi and Vassileva (2017) reviewed and recognized the limitations of several grouping algorithms, and owing to these limitations they proposed a group matching algorithm using the principles of the Hungarian algorithm, with some constraints to obtain groups with diverse skills. Y. Zheng *et al*. (2018) proposed an improved genetic algorithm using an integrated mathematical model to identify the group formation requirements.

Some researchers argued that heterogeneous groups allow students within the groups to learn from each other, which leads to more innovative and creative behaviors. For example, (Pang *et* *al*., 2014) proposed a clustering-based grouping model that adopts a balanced K-means algorithm in order to divide the students who are more similar into clusters, then adopts a one-sample-each-cluster strategy to build the diversified groups. Others have claimed that students in homogeneous groups can make progress at a similar rate, which is better to achieve specific objectives (Bekele, 2006).

Overall, a collaborative e-learning platform on privacy-awareness has yet to be addressed. Thus, in this research, we combine both privacy education and a collaborative e-learning environment in one platform. Moreover, we propose a stable student-based matching algorithm based on the theory of matching game. The proposed algorithm enables stable matching between students in the sense that no student has an incentive to leave his/her current partner(s) and work with another one.

Chapter 3 – The Proposed Collaborative E-learning Platform on Privacy Awareness

This platform provides a collaborative environment, which allows each student to learn, to share knowledge and ideas with their partner(s), and to solve quizzes together. Moreover, the proposed platform allows us to avoid the typical problems associated with traditional collaborative environments, which are basically caused by studying with incompatible partners, since negative effects may arise if there is lack of careful consideration in the partner selection procedure.

For this purpose, we adopt a stable matching algorithm, based on game theory, which guarantees the choice of optimal partners depending on their knowledge and behavior history.

Since our platform is targeting teenagers (Generation Z), we take into consideration the learning preferences of this generation. In fact, Generation Z learning tendencies include video learning (Almeida & Almeida, 2016), collaboration with peers (Petrunich-Rutherford & Daniel, 2019), competition, and gamification. Therefore, we applied these learning preferences in the proposed platform.

In the following sections, we first talk about the course design phase, followed by the proposed architecture of the platform.

3.1. Course Design

To provide context for our platform, the Personal Data Protection Competency Framework for School Students (PDPCFSS)[12] was adopted as an outline to guide us on how to build our platform and create our courses. This framework was proposed by the Privacy Commissioner of Canada to the Council of Ministers of Education[13] after the 38th International Conference of Data Protection and Privacy Commissioners, as a solution to the risks associated with connecting to the Internet.

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[12] International Digital Education Working Group (2016). Personal Data Protection Competency Framework for School Students. 38th International Data Protection and Privacy Commissioners' conference ICDPPC. accessed 22/01/2020

[13] Joint letter to the council of ministers of education: https://www.priv.gc.ca/en/opc-news/news-and-announcements/2017/let_171103/ accessed 22/01/2020

In the following sub-sections, we present our course design methodology, then we illustrate examples of our methodology's steps.

3.1.1. Course Design Methodology

To create our courses, the above-mentioned framework (PDPCFSS) was adopted. This framework consists of the knowledge outcomes and the skills outcomes of nine essential privacy principles that students should know and understand. These principles can be described as follows: (1) personal data; (2) privacy, civil liberties and protection of personal data; (3) understanding the digital environment – technical aspects; (4) understanding the digital environment - economic aspects; (5) understanding personal data regulations and legislation; (6) understanding personal data regulations: controlling the use of personal information; (7) managing my data: learning to exercise my rights; (8) managing my data: learning to protect myself online; and (9) the digital world: becoming a digital citizen.

We have built our courses for the proposed platform based on the above nine principles. To present these courses, we have adopted a video-based learning method that is preferred by teenagers, since they tend towards visual elements, graphics, storytelling (Wolfe, 2001), short videos (Almeida & Almeida, 2016), and small learning units. For this purpose, we designed animated short videos to demonstrate the context of our courses.

Our learning method consists of two parts: knowledge acquisition, represented by micro-videos that provide quick and focused information, and skills acquisition, represented by short quizzes that focus on case-based questions that present real situations.

The video-based learning method allows us to better explain the context of courses compared to the traditional text-based learning method. This is because we can use illustrative graphics through a conversation between characters and tell stories. Thus, concepts are transformed from "theory" to "practice" and have been made into visual materials. This is useful as it can remain in a students' mind for longer, as the brain reacts to visuals more effectively than text (Bergwall, 2015).

To build our courses, we took the above nine principles as modules, and divided their knowledge outcomes into topics. The following steps explain our methodology for designing courses in the proposed platform.

Course Design Methodology

For each module, do the following:

Step 1: Knowledge acquisition (vocabulary-based approach): analyzing the knowledge outcomes, extracting the essential concepts, and combining the related ones to extract topics.

Step 2: Ordering topics by considering the prerequisites first.

Step 3: For each topic:

- **Step 3.1:** Identifying component parts, which can be as concepts, problems, positive and negative sides, etc.
- **Step 3.2: For each component:**
  - **Step 3.2.1:** Collecting information from references, such as definitions, concrete examples, situations or real stories.
  - **Step 3.2.2:** Summarizing or rephrasing ideas in a simple language or converting it into dialogue.

Step 4: Designing a scenario to relate the components, including introduction, definitions, discussions, stories, examples, advice, and conclusion, which covers all of the components.

Step 5: Creating a short time video with this scenario and focusing on visual components related to subjects, such as graphics.

Step 6: Creating a short quiz covering all components and focusing on case-based multiple-choice questions (MCQ), in order to develop a student's skills.

The following section shows examples of how to apply our methodology.

3.1.2. Illustrative Examples of our Methodology

Steps 1 and 2: Knowledge acquisition and ordering topics. For example, in Module 1, "personal data", the knowledge outcomes in the framework were analyzed in order to extract the following five principle concepts: personal data, pseudonymity, data re-identification, technical data, and sensitive data. Then, the two related concepts, personal data and sensitive data, were combined into one topic. Finally, we obtained the following ordered topics: personal information, pseudonymity, de-anonymization, and metadata. Figure 1 illustrates these steps.

Step 3: For each topic in this module:

Step 3.1: Identifying component parts. We identify component parts that are related to this topic, such as related concepts, problems, and positive and negative sides. Figure 2 demonstrates how we identified the component parts for each topic in Module 1.

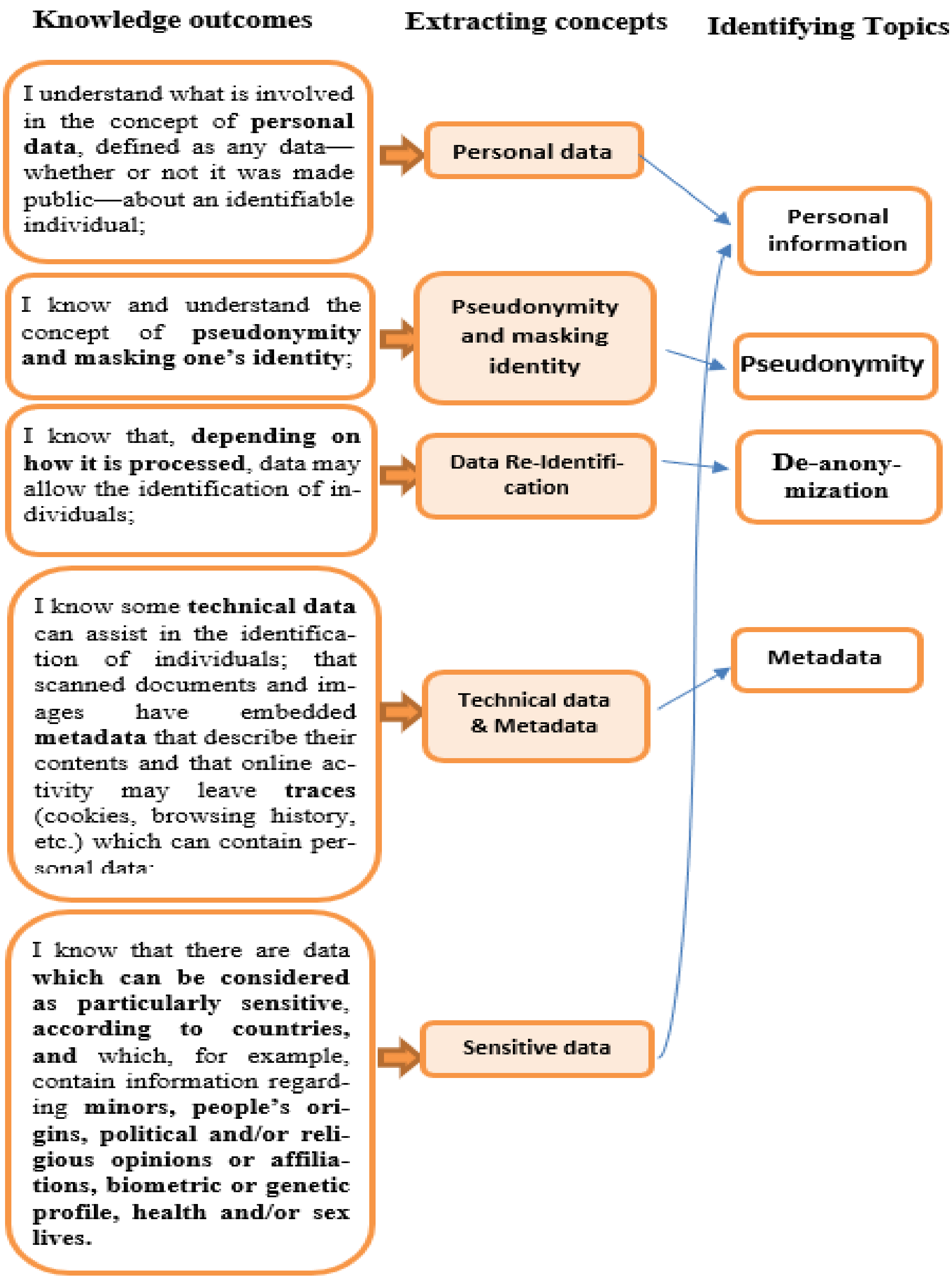

Figure 1: Knowledge acquisition in Module 1, obtained by extracting the essential concepts from knowledge outcomes, and combining the related ones to extract topics.

Topic 1:

Personal information

- What is personal information
- Why is it important to protect it?
- Online information is permanent.
- What is sensitive information (political opinions, religion or affiliations, biometric profile, health data)

Topic 2:

Pseudonymity

- The concept of pseudonymity and masking identity.
- The concept of anonimity
- Why people use pseudonymity?
- Positive side
- Negative side

Topic 3:

De-anonymization

- Combining information make something bigger.
- Online information is permanent.
- Tracing people is possible by collecting an combinig information.
- Some information may allow someone to uniquely identify you, even when you use pseudonym.

Topic 4:

Metadata

- What's metadata
- How metadata collected
- Examples of metadata generated while communicating online.
- Metadata can be more revealing than content itself.
- Digital footprint
- Who is collecting this data and why?
- What does cookie mean?

Figure 2: Identifying the component parts for each topic in Module 1

Step 3.2: For each component:

Step 3.2.1: Collecting information from references. In this step, we collect information from references to provide the proper context for our courses. This can be, for example: definitions, explanation texts, concrete examples, situations or real stories.

For example, to find the following component: "Why people use pseudonymity?", we used a survey result about anonymity in the social lives of adolescents (Ellison *et al*., 2016) to answer this question realistically. Figure 3 shows how the survey's results have been used in our courses. As another example, the real story of Andrew[14] was used to show the negative side of pseudonymity (see Figure 4).

In general, the most important sources that we have used frequently are "Office of the Privacy Commissioner of Canada"[15], and the Privacy K-12 Curriculum Matrix (Solove, 2015).

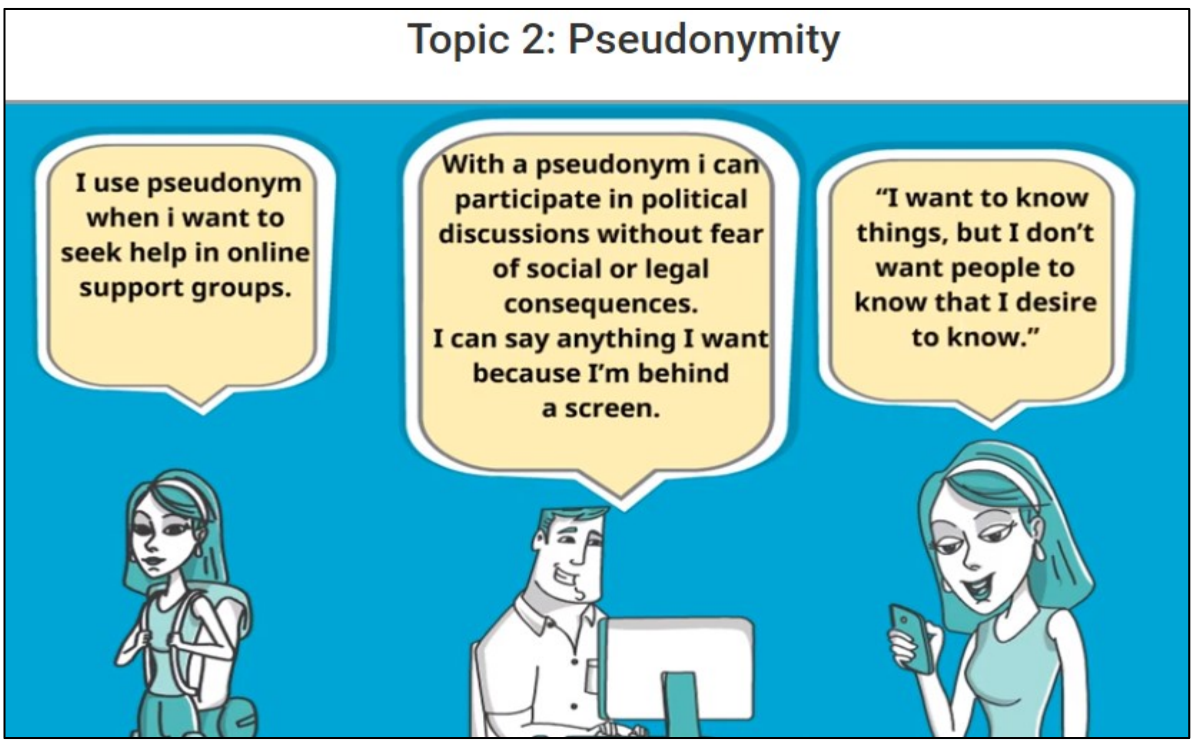

Figure 3: Why do people use pseudonymity?

[14] "Teen Found After Meeting His 42-year-old Online 'soulmate'". Globe and Mail. www.theglobeandmail.com/news/national/teen-found-after-meeting-his-42-year-old-online-soulmate/article4187232/

[15] Office of the Privacy Commissioner of Canada+ https://www.priv.gc.ca/en/privacy-topics/privacy-and-kids/

Step 3.2.2: Summarize or rephrase ideas in a simple language. In some text, we may need to express the idea in an alternative way in order to simplify the concepts or change some details. Figure 4 shows an example of how the text in the story of Andrew was rephrased and converted to a conversation between him and his mother, to show the negative side of pseudonymity.

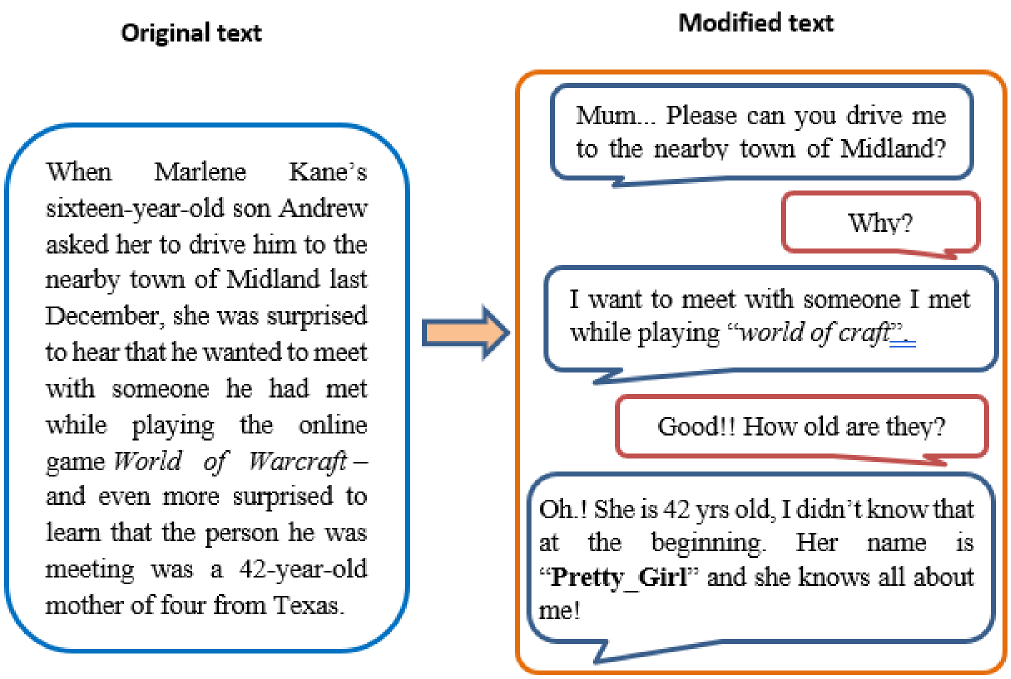

Figure 4: Rephrasing the text in Andrew's story

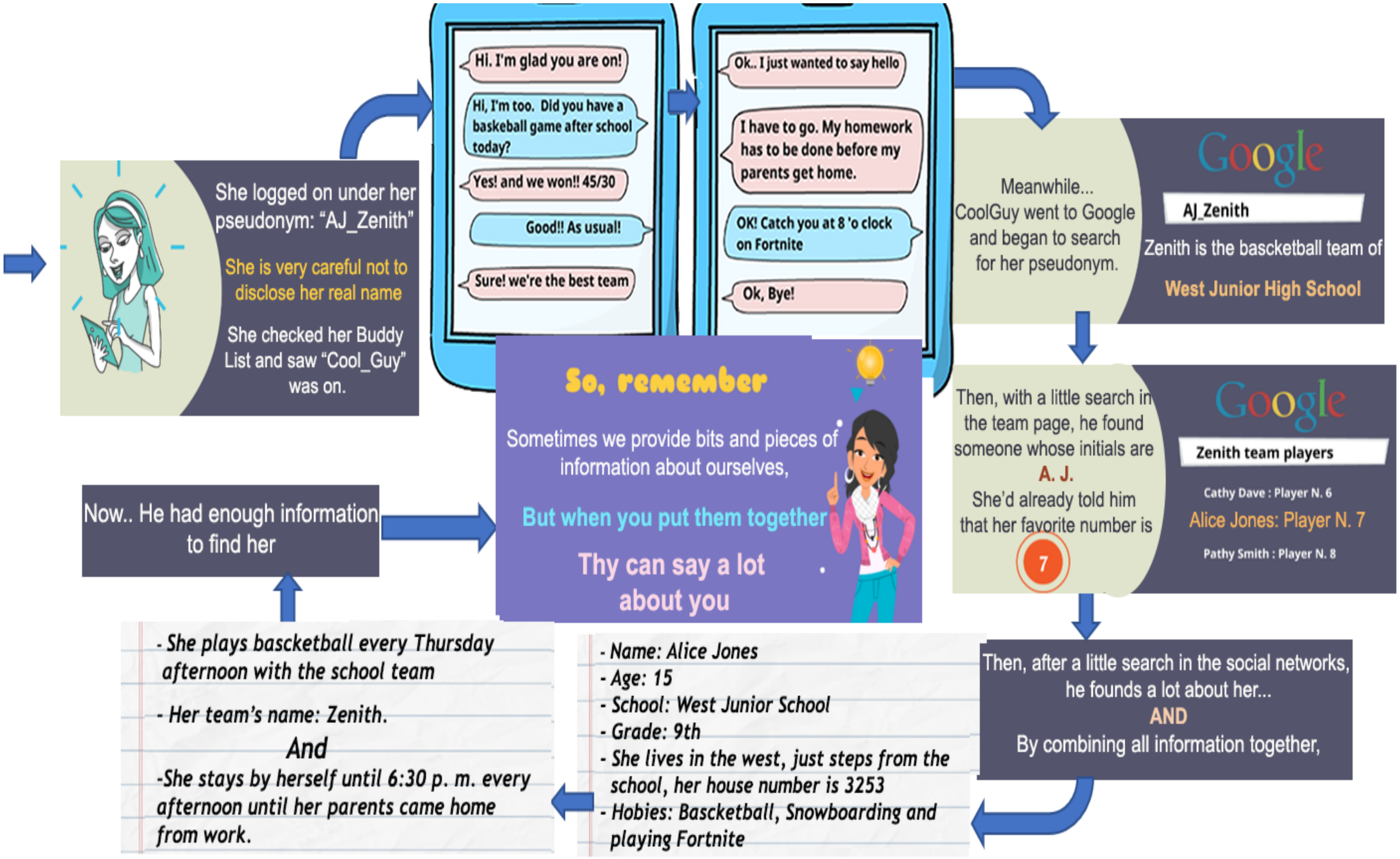

Figure 5: Example of a story scenario

Step 4: Creating a scenario to relate the components, including introduction, definitions, discussions, stories, examples, advice, and conclusions. The scenario can be either a story scenario or a course scenario.

Story scenario: See example in Figure 5 where we have written a scenario inspired by the story of Shannon[16] with some changes to match the content of the topic.

Discussion scenario: For most of the courses, we used a discussion between two characters to explain the context of the topic. Thus, we converted a normal text to a dialogue. Figure 6 shows an example of a discussion scenario.

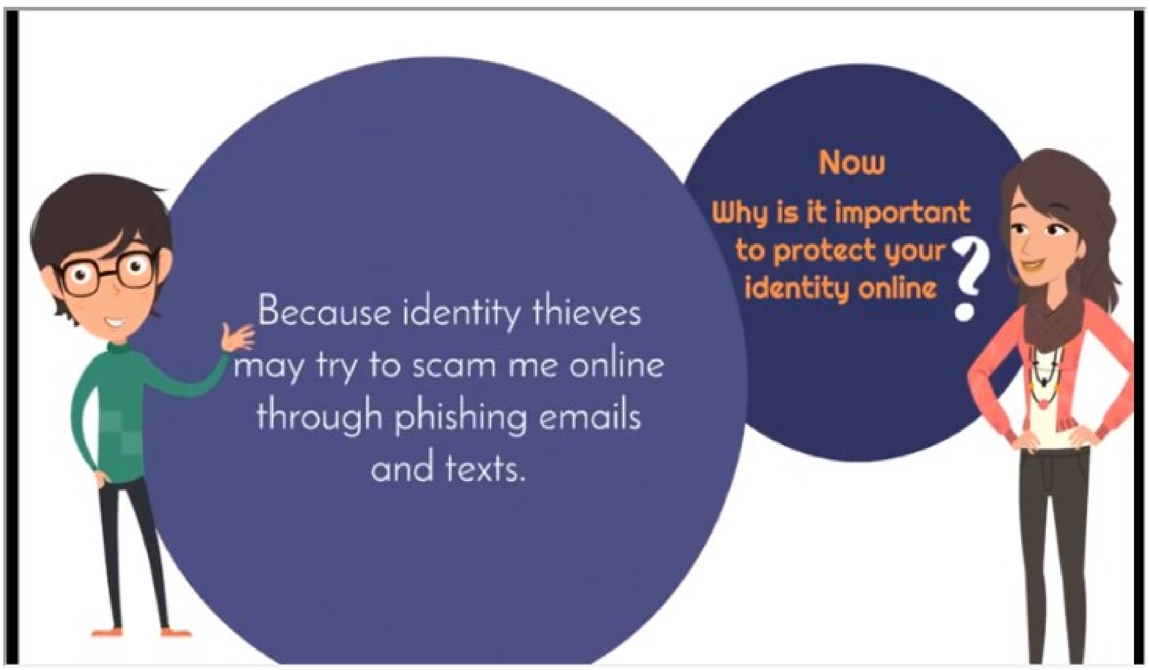

Figure 6 : Example of discussion scenario

Step 5: Creating a short video: with all of the materials obtained from the previous steps, such as texts, scenarios, examples, and stories, everything is now ready to create the video that is the knowledge acquisition part in our learning method. To this end, we designed short animation videos that contain all these materials ordered and displayed by sequence with illustrative graphics. Therefore, in this we transformed these materials from text to visual.

[16] "*It Could Happen To You*": http://parentarium.com/could_someone_find_you_if_they.html accessed 20/08/2019

We used "Animaker[17]" to create the animation videos, a cloud-based software that has a large library of illustrative content to make explanatory videos. Figure 7 shows an example of one of our animation videos.

Figure 7: A short video on the topic "Ethical respect for other's privacy"

Step 6: Creating a short quiz that covers all components. This step is very important as it is considered as skills acquisition or training time to develop a student's skills (Valiente *et al*., 2016). We focus on case-based questions that present real situations with multiple possible choices, thus the student can decide on how he/she will react in this situation by selecting one answer from a specific list of choices. Moreover, each answer is weighted, and suitable feedback prepared for each question. Figure 8 shows an example of a question with feedback.

[17] www.animaker.com

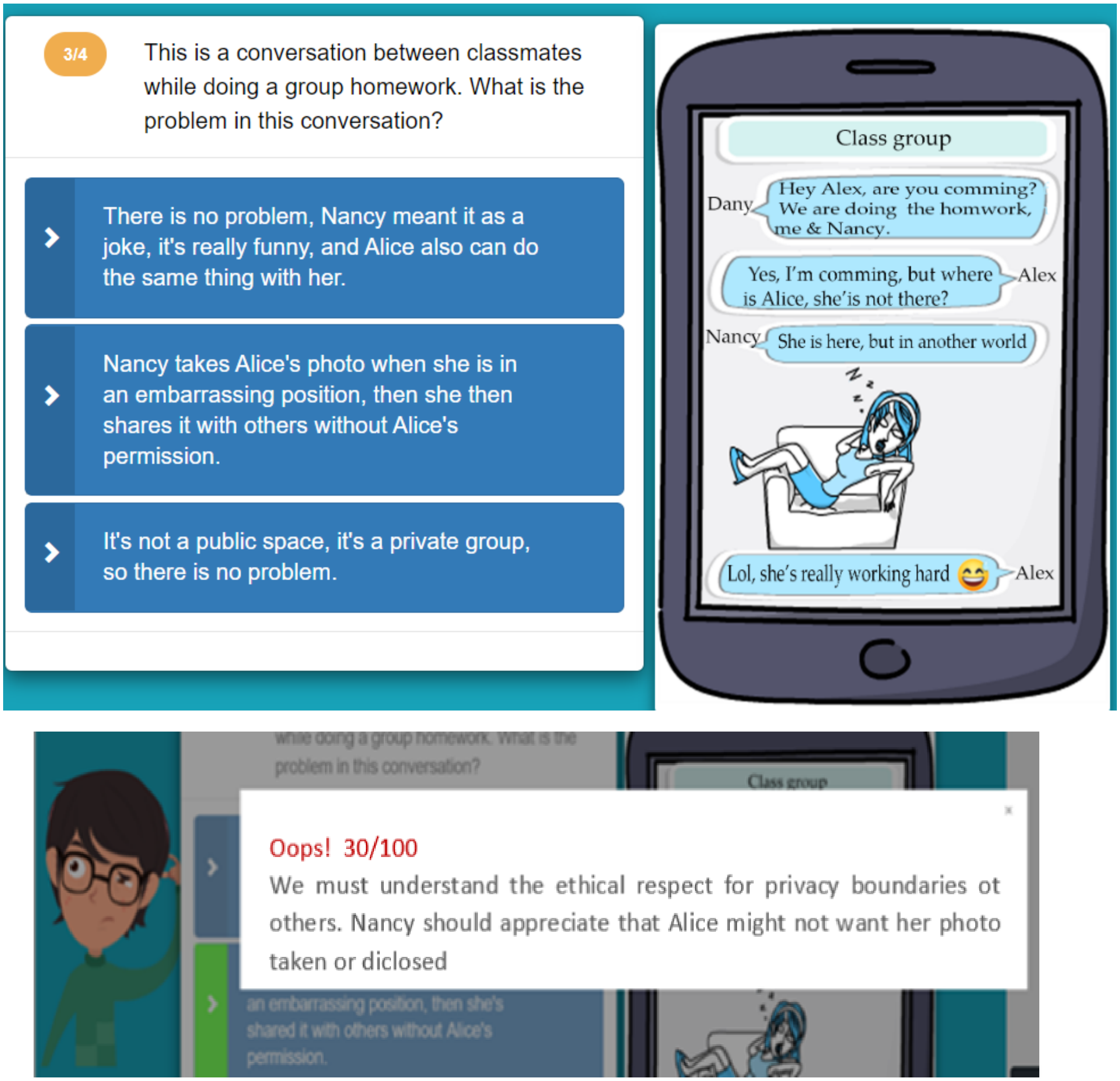

Figure 8: Example of quiz question and feedback

Finally, by completing the course design phase, all the materials are ready to build the proposed Collaborative E-learning Platform on Privacy Awareness “Teens-Online”. Our material consists of nine modules, with each module divided into topics, and each topic consisting of one five-minute animation video and a short quiz. In the next section, we will talk about the architecture of the proposed platform and all its components.

3.2. Platform Architecture

This section introduces the architecture of the proposed platform, which consists of seven essential components. As shown in Figure 9, the components are as follows: a partner selection module, collaborative environment module, domain model, tutor model, student model, user interface, and learning style model. The partner selection module contains all the procedures of partner selection, including selecting preferences, executing the proposed matching game algorithm, and evaluating students' behavior. The collaborative environment module contains the processes of collaborative quizzes, the chat tool, and the discussion forum. The domain model contains the material, divided by modules and topics. The tutor model controls many processes, such as which lesson to take according to the student model, give feedback on quizzes, and manage the matching game processes. The student model provides all required information, such as the current state of a given student. This is useful to execute the above-mentioned processes automatically and adaptively for the student. The user interface has two parts, one for the student and the other for the administrator or the teacher. Learning style represents the methods that we have adopted to present our courses. These methods are Microlearning and Gamification.

It is worth noting here that, to conserve students' privacy, the platform uses the pseudonym and avatar that the student has chosen when they signed up.

Figure 9 shows the basic architecture of the proposed collaborative e-learning platform "Teens-Online", while Figure 10 shows the detailed architecture of the proposed platform.

The following sections discuss each of the elements mentioned above and their functions.

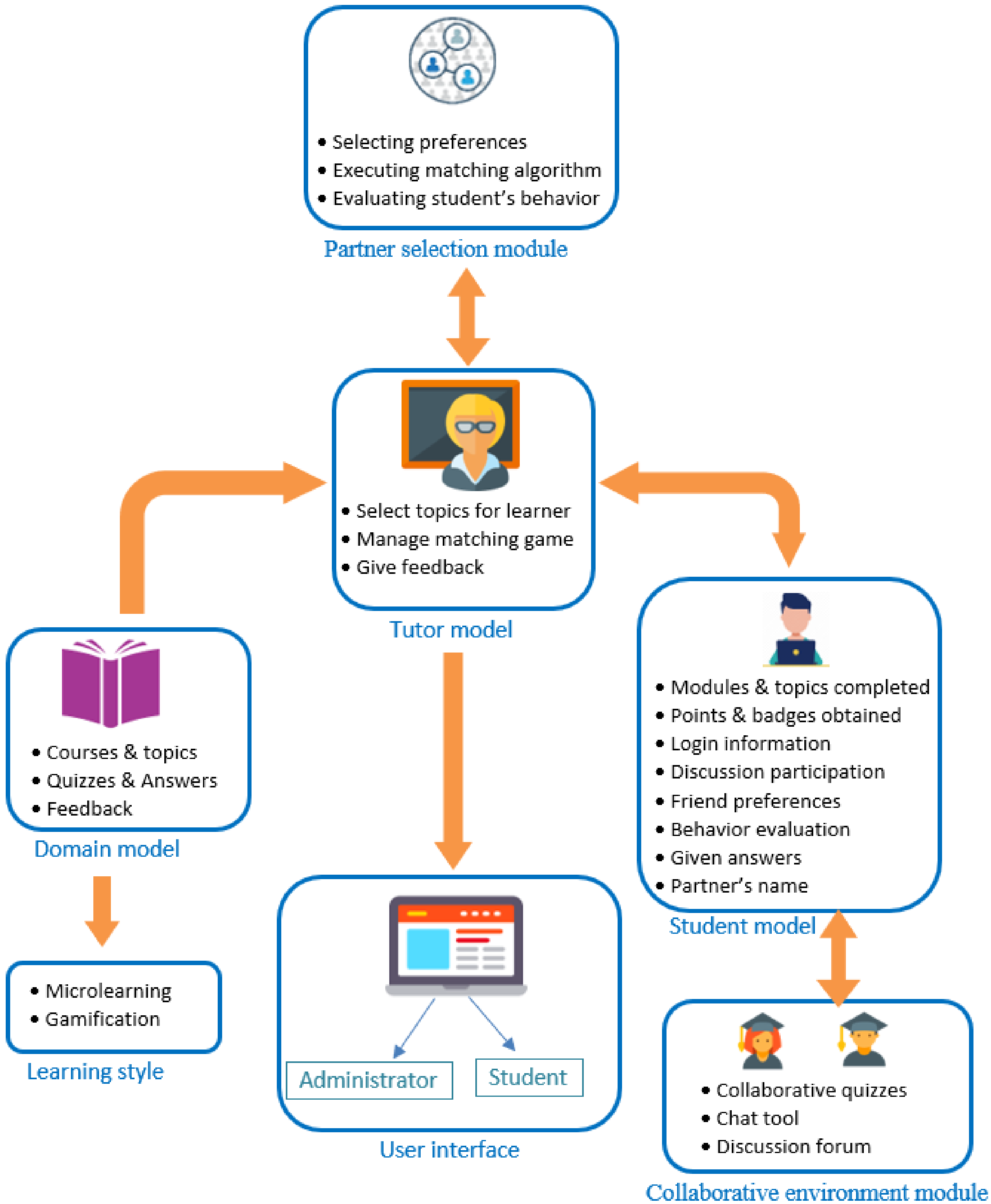

Figure 9: Basic architecture of "Teens Online"

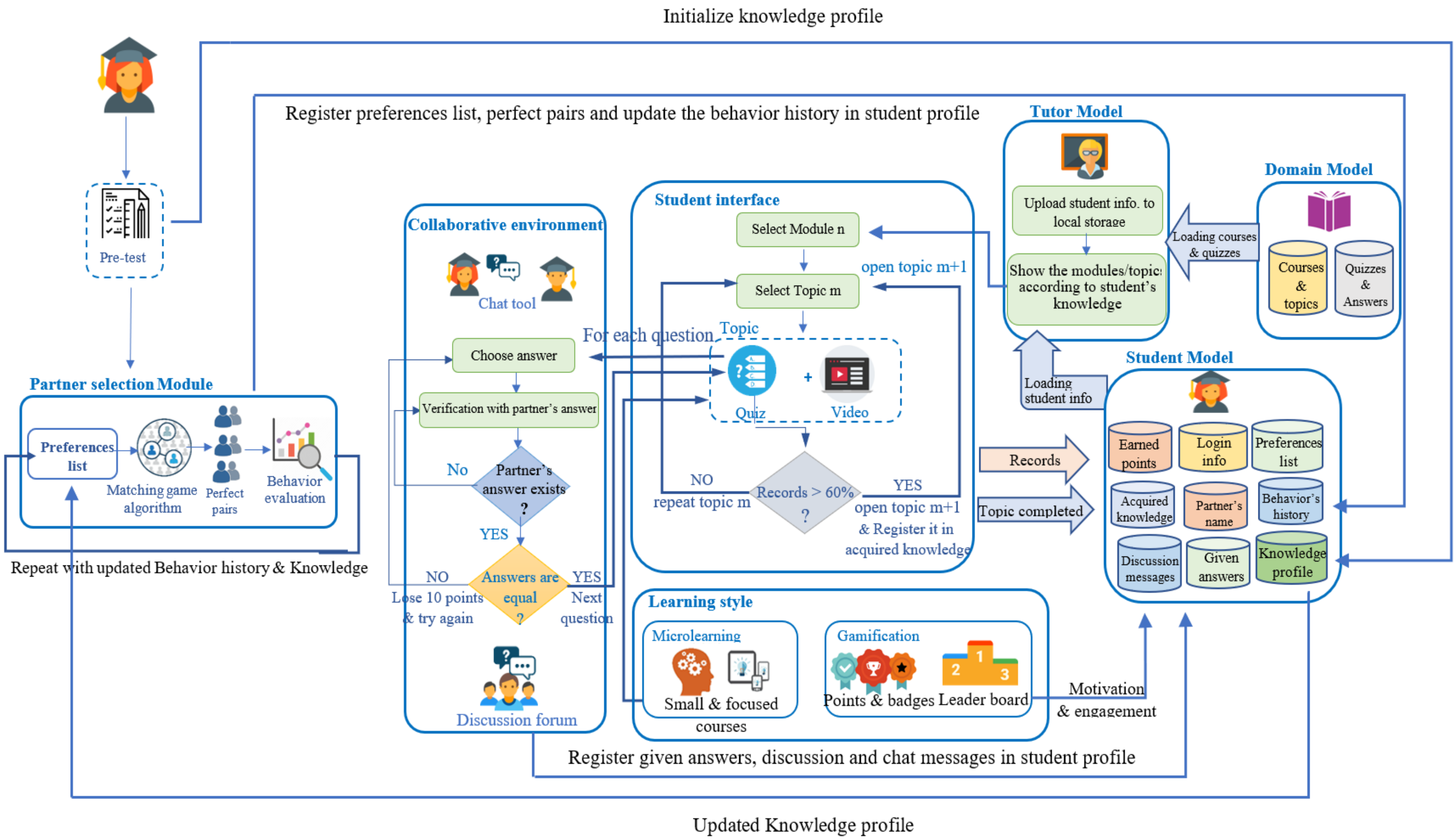

Figure 10: Detailed architecture of the Collaborative E-learning Platform on Privacy Awareness "Teens-Online"

3.2.1. The Partner Selection Module

In our platform, we provide a collaborative environment that allows each student to share knowledge and ideas with his/her partner(s). Meanwhile, one of the critical issues experienced by traditional collaborative environments is the lack of mechanisms for selecting the optimal partner(s). Usually, the process of selecting a partner(s) is done by one of the following three methods: randomly, self-selected by the student, or criterion-based method (Y. Zheng *et al*., 2018). The random solution is the easiest and fastest: a teacher or a computer system splits students into groups randomly. This approach enables all students to be mixed together in order to achieve diversity inside the groups (Sadeghi & Kardan, 2016). The second approach, self-selected group composition, enables students to create groups on their own that can generate greater empathy among group members. Previous work has shown that studying in self-selected groups is better than in randomly assigned groups, in terms of learning outcomes (Chapman *et al*., 2006). Nonetheless, this self-selection method may have negative consequences as it may create groups based on incompatible factors, such as friendship, rather than pedagogical factors (Moreno *et al*., 2012). In the first two methods, the student is not sure whether the candidate partner(s) really want to collaborate with her/him or not. Moreover, he/she can be rejected, and that can create a psychological problem for the student. Furthermore, working with an incompatible person may inhibit the education process. According to Cruz and Isotani (2014), team composition without careful consideration (i.e. randomly) leads to problems such as demotivation, unequal participation of individuals, and resistance to group work in future activities. Therefore, partner selection is an important process and should not be done randomly.

To address the above-mentioned problems, many studies used the third method, criterion-based selection, to form well-structured groups according to specific criteria and algorithms.

By conducting a survey of the literature on collaborative learning and knowledge sharing, Thanh *et al*. (2019) classified the characteristics that influence group formation into two categories: (1) *Academic factors* such as skills, learning styles, learning patterns, academic interests, and education level; and (2) *Socio-psychological factors,* such as personality, willingness to communicate, self-perception of being connected, hobbies, demographics, etc.

In our platform, the two categories are established by identifying *Knowledge factors* and *Behavior factors*. *Knowledge factors* consist of topic-specific knowledge levels of students. Using these factors increases the benefits of collaboration by pairing students who can support each other based on complementary competences. *Behavior factors* consist of personality traits considered essential to improve the collaborative work and student success.

This work proposes a stable matching-based selection using a matching game algorithm, in the sense of choosing the optimal partner(s) for each student depending on his/her preferences. More specifically, we adopt the “stable marriage algorithm” (Gale & Shapley, 2013; Genc *et al*., 2017) in order to obtain a stable one-to-one match between the students of two groups (i.e. two classes) to enforce the collaboration among students from different backgrounds. It is worth mentioning here that the proposed stable matching-based selection can be modeled using the “Stable Roommates Problem” (Irving, 1985) to match students without dividing them into different groups. However, we prefer to adopt the “stable marriage algorithm” to accommodate two groups, as it is a more general approach.

The stable marriage algorithm can be used for the purpose of pairing two sets of elements such as men to women, doctors to hospitals (Nguyen & Vohra, 2018), etc. The purpose of using this algorithm in the proposed platform is to guarantee a stable match between students and their partners. The stability of a match is achieved when there is not a matched pair that both prefer each other more than their current partner under the match. The stability of this algorithm has already been proven (Gale & Shapley, 2013).

The proposed matching game algorithm allows each student to select his/her partners according to his/her preferences. This matching game can be played repeatedly in multiple stages, in order to improve the selection with the updated information. In the first stage, the selection process is based on students’ knowledge (topic-specific knowledge level). In the next stages, the selection process is based on students' knowledge and their behavioral history. In particular, each student has their behavioral history evaluated by his/her partners, which frequently improves the quality of selections.

So, in this module, the procedures are divided as follows: knowledge-based selection, behavior's evaluation and hybrid selection. In the following sections, we discuss these different stages in detail.

a. Knowledge-based Selection

This selection can be considered as a bootstrap phase as the students do not have behavioral histories yet. Therefore the selection process (i.e. preferences) is based only on the student's knowledge profile. The knowledge profile reflects the topic-specific knowledge level of the student, which is initialized by a pre-test[18] and changed adaptively when a student goes through the course and completes the quizzes. This profile contains the student's scores on the five main concepts of the courses: (1) privacy; (2) security; (3) technical aspects; (4) economical aspects; and (5) regulations and legislation.

Once a student signs up, he/she chooses group A or B, which can be, for example, two classes or two schools. In this stage, students are already divided into two groups of N students, group A and group B. Each student ranks the students in the other group according to his/her knowledge needs. We consider intuitively that students have varying understanding levels and different interest levels with respect to the five principal concepts mentioned above, so a student can prefer to work with another student who has complementary competences.

In this process, the selection is anonymous, in order to guarantee that the selection is based only on students' knowledge and not on their identity. According to Pizzato *et al*. (2013), the use of implicit profiles is more effective, therefore, the selection will not be influenced by other factors (e.g. personal relationship or gender). At the same time, this process should be done anonymously for the purpose of privacy (Orji, Greer, *et al*., 2019), to prevent the student intimidation. In this stage, a student can rank his/her preferences according to her/his knowledge needs, where he/she can see the knowledge qualities of others by clicking on their (anonymous)_avatars. The knowledge history shows the score achieved for each criterion (e.g. security 4/10, privacy 9/10, etc.).

[18] See the pre-test in the appendix.

So, a student $a \in A$ creates a preference list p_a that contains a set of ordered students from B, and the same for each student $b \in B$ will create a preference list p_b, so we have:

$$p_a: A \to B^N \; \forall a \in A \; and \;\; p_b: B \to A^N \; \forall b \in B \qquad (1)$$

B^N and A^N are the lists of N students.

All preferences will be registered in the database. Figure 11 and Figure 12 show the ranking process in a student's page and the creation of the preferences list.

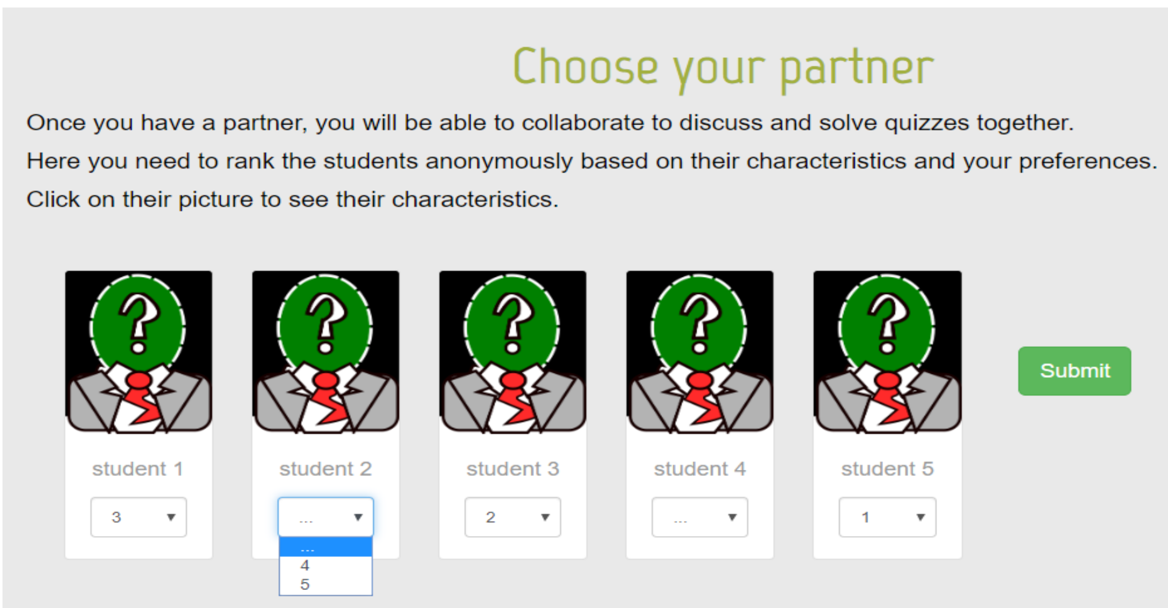

Figure 11: Screenshot of student's page while ranking his/her preference list (knowledge-based selection)

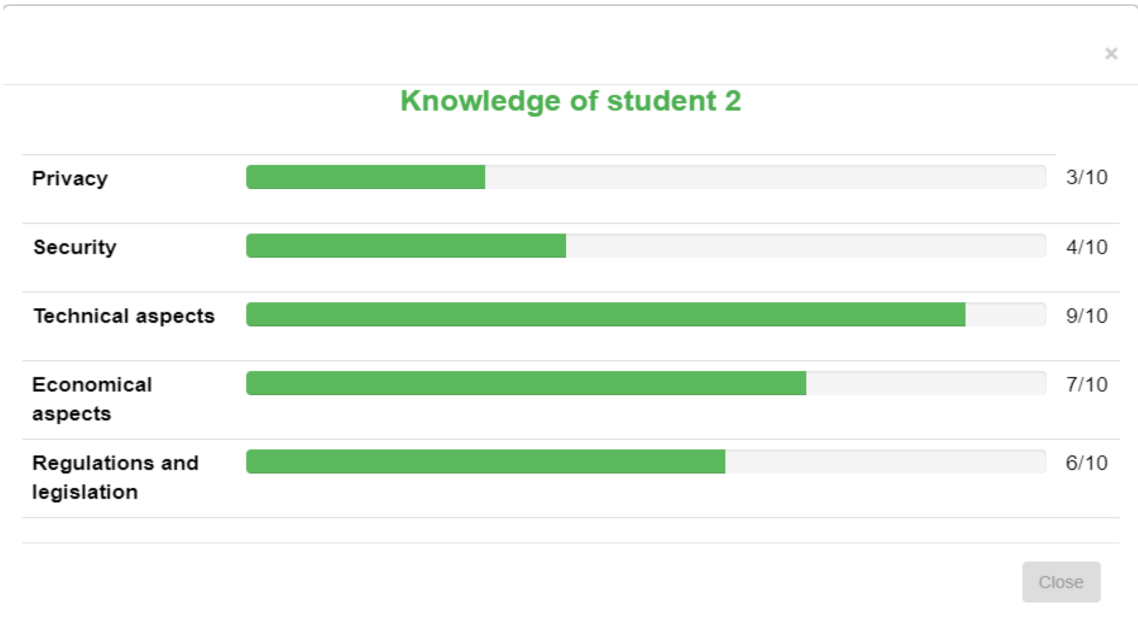

Figure 12: Student's knowledge as shown by clicking on each student.

Once all students select their preferences, the admin will click on the "Matching" button. By clicking on this button, the system will match students by getting all preference sets pa, pb from the database and executing the implemented stable matching algorithm to obtain the optimal matching M, which is a set of matched pairs (a,b) ∈(A×B).

In the following, the pseudo-code of the proposed matching algorithm is presented.

GTPS Algorithm

Game theory-based partner selection algorithm

```
Input: two preference sets pa, pb
pa ∀a ∈ A
pb ∀b ∈ B
function stableMatching {
  Initialize M to empty matching.
  while (∃ a is unmatched and hasn't proposed to every b) {
    b ← first student on a's list to whom a has not yet proposed.
    if (b is unmatched)
     Add (a, b) to matching M.
   else (in case of pair (a', b) already exists)
     if (b prefers a to current partner a')
       Replace (a', b) with (a, b) in matching M.
       a' become free
     else
       b rejects a.
  }
  return stable matching M.
}
Output: M which is a set of matched pairs (a,b)∈(A×B)
```

In this algorithm, the system will match two disjoint sets of students A and B, taking as input the preference sets p_a and p_b, and giving the stably matched pairs as an output. The processes of the algorithm are as follows:

1. All students have ranked students of the other group according to their preferences (built the preference lists p_a and p_b).
2. One of the two sets is chosen to make proposals. Here we choose group A's set (p_a) to be the proposing set.

3. One individual from the proposing group who is not already engaged will propose a match to their most preferable option who has not already rejected them.
4. The person being proposed to will:
   - Accept, if this is his/her first offer.
   - Reject, if this is worse than his/her current offer.
   - Accept, if this is better than his/her current offer. In this case, he/she will remove the previous offer.
5. When all members of the proposing group are matched, the loop terminates. The currently matched pairs are now stably matched. This means that there does not exist any pair (a, b), where both prefer each other more than their current partner under the matching.

This algorithm has a quadratic time complexity $O(n^2)$, so it terminates after at most n^2 iterations of WHILE loop.

Here is an example of two 5-student groups. Table 1 shows the “ranking matrix” of students from group A and students from group B.

Table 1: The “ranking matrix” of students from group A and students from group B

GrA\GrB	**Eve**	**Max**	**Alex**	**Sara**	**Alice**
Jados	1,5	2,5	3,3	4,5	5,5
Roy	4,3	5,4	2,2	3,3	1,4
Jason	3,4	1,2	4,1	5,4	2,3
Cam	3,2	5,1	4,4	2,2	1,1
Sam	4,1	2,3	1,5	5,1	3,2

In the matrix, the first number of each pair gives the ranking of students in group B by students of group A. The second number is the ranking of students in group A by students of group B. Thus, *Jados* ranks *Eve* first, *Max* second, *Alex* third, *Sara* forth and *Alice* fifth, while *Eve* ranks *Sam* first, *Cam* second, *Roy* third, *Jason* forth and *Jados* fifth, etc. So, the system will get this matrix as an input and will give the matching pairs as an output. The highlighted boxes are the results of the chosen partners by the implemented matching algorithm.

Figure 13 shows an example of the preferences' sets for the above two groups, as well as the matching algorithm procedures and the obtained results of perfect matching pairs.

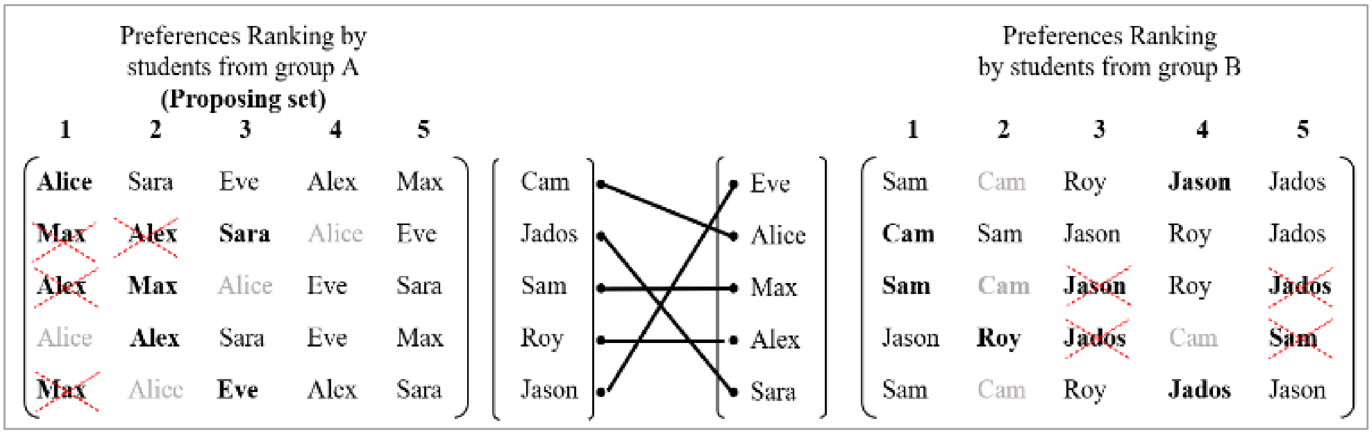

Figure 13: Example of the matching algorithm processes with the preferences sets and the obtained matching pairs.

According to the algorithm steps, we can observe the following procedures:

Cam was matched to Alice, Jados was matched to Max, Max rejected Jados for Jason, Sam was matched to Alex, Alex rejected Sam for Jados, Alex rejected Jados for Roy, Max rejected Jason for Sam, Jados was matched to Sara, Jason was matched to Eve.

And finally: Alex paired with Roy, Alice with Cam, Eve with Jason, Max with Sam, and Sara with Jados.

GTPS stability: Under the above procedures, the GTPS algorithm seeks a complete one-to-one matching between the two groups, which satisfies stability. Stability requires the concept of a blocking pair. Two pairs (a_i , b_p) and (a_j , b_q) are blocked by the pair (a_i , b_q) if a_i , prefers b_q to b_p and b_q prefers a_i to a_j , as illustrated in Figure 13. A complete matching without being blocked is called stable matching (Morizumi *et al*., 2011). In other words, in this matching there are no pairs *(a,b)* where *a* and *b* both prefer each other rather than their current partner under the matching.

Therefore, we can say that the proposed partner matching algorithm respects the reciprocal benefit of each pair, as it considers the preferences of both partners.

The obtained matched pairs appear on the admin’s page. Meanwhile, they will be registered in the database, and each student will receive his/her partner’s name in his/her page.

In this work, we premise that both groups have the same number of students. However, the proposed algorithm can efficiently accommodate the case of unequal groups by associating a quota determined by each student. This quota represents the number of team members that each student desires to collaborate with (Biró, 2008).

b. Behavioral Evaluation

This stage allows student to have or update his/her behavioral history, which is evaluated by his/her partners, in order to use it as a criterion in the GPTS algorithm.

Given that the proposed platform is collaborative, we should consider the problems experienced by a student while working with others. Barron B. (2003) showed that sometimes group members do not pay attention to the opinions of others, interrupt them, and reject alternative suggestions without justification (dominant student problem)(Quinn & Eckerson, 2010). Also, some members might be non-cooperative, or their contributions are dispensable (free rider problem) (Refeque *et al*., 2018), and some of them do not respect time. These problems can impede the expected benefits of collaborative work.

To address the above-mentioned problems, we propose a mechanism where each student can evaluate his/her partner(s) based on their behavior and interaction. Therefore, once a student has a partner(s), he/she can perform the evaluation at any time by clicking on the “Evaluate your partner” button on the student’s page. The evaluation can be done repeatedly, and the evaluation's results will be registered in the student's profile cumulatively.

This strategy allows students to improve their selections and learn from their experience, as well as to motivate students to do their best, since they know that they will be evaluated. Figure 14 shows how a student can evaluate his/her partner.

For this evaluation, we adopt Meador's research (Meador, 2019) to define the essential personality traits that help students succeed, as well as improve their collaborative work. We chose seven positive personality traits from Meador's research, which corresponded to our work. These traits are conscientiousness, gregariousness, independence, intuitiveness, kindness, passionate, and respectfulness. We considered these traits as behavioral evaluation criteria.

For each criterion, the student can give a score to his/her partner(s) from 0 to 10, where 0 represents the worst score and 10 represents the best score.

It is worth noting here that neither student pairs nor a student themselves can explore their behavior history in order to address the ethical problems resulting from disclosing student's behavioral information.

Figure 14: Screenshot of the student page while evaluating his/her partner.

c. Hybrid Selection

This selection is based on students' knowledge and behavioral history. When all evaluations have been completed by students, and each student has a behavioral history, a new phase of selection will be activated. This phase of selection is similar to the first stage (knowledge-based selection), but in addition, students rank their preferences based on the behavioral history of their partners as well, according to his/her knowledge needs. Both behavioral qualities and the knowledge profile of each student can appear by clicking on their anonymous avatars. The behavioral history shows the score achieved for each criterion (e. g. independence 8/10). Figure 15 shows the ranking process of this stage.

After all the students have chosen their preferences, the admin executes the proposed matching algorithm again with the new lists of preferences. This stage can be repeated (e.g. after each module).

By applying the above-mentioned steps, we can say that the integration between the proposed partner matching algorithm and partner's knowledge and behavior has been done successfully. This improves the quality of selection, and therefore enhances the teamwork performance and increase the benefits of collaborative learning.

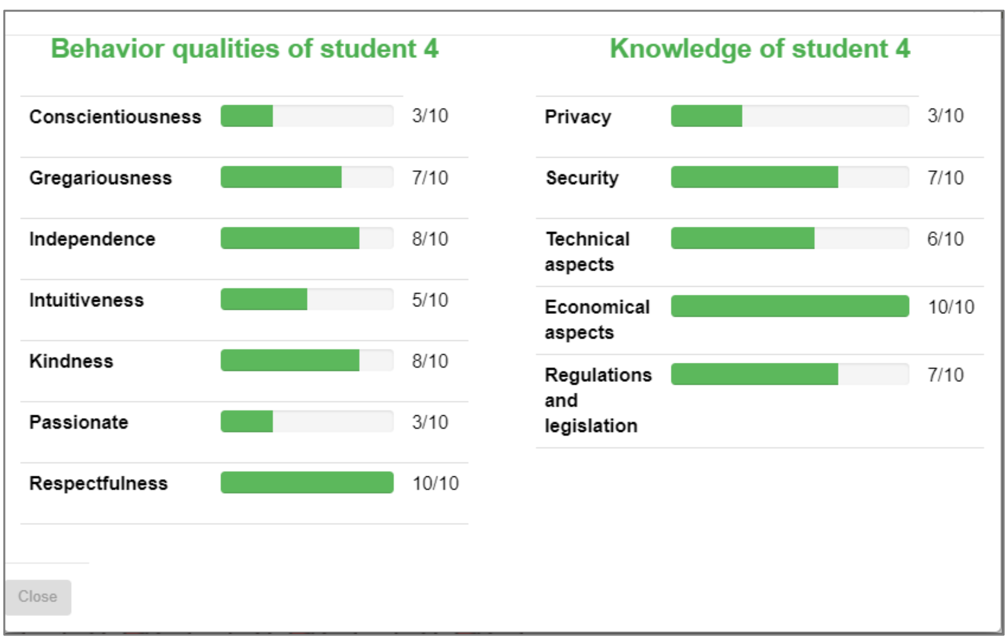

Figure 15: Student's behavior and knowledge history as shown by clicking on each student's avatar.

3.2.2. The Collaborative Environment Module

Once the proposed matching algorithm has been executed, each student becomes ready to collaborate with his/her partner(s). The proposed platform provides an environment that enables students to solve quizzes together and allows them to discuss and interact by text. This allows students to exchange knowledge and experiences while they are solving the quizzes.

Many research studies talk about the benefits of collaborative quizzes to help students get in-depth knowledge and a better understanding of the course material (Petrunich-Rutherford & Daniel, 2019). Thus, it raises the performance of the students and their learning outcomes.

The proposed platform adopts this successful approach of collaborative quizzes (Petrunich-Rutherford & Daniel, 2019). More specifically, when a student clicks on the quiz button, he will be informed that this task should be done with his partner in collaborative work as a team. In other words, they should solve the quiz together and achieve consensus on their answers for each question, otherwise they will be unable to proceed to the next question (Figure 16). The student and his partner can discuss questions using the proposed chat tool to gain consensus on their answers. It is worth noting that a student has no incentive to provide an answer that is not equivalent with his partner's answer or give a random response, since some points will be deducted from his account (in our platform, the student will lose 10 points). Therefore, students are encouraged to collaborate all the time.

With this strategy, we guarantee that students will have the chance to discuss with their partners, present and defend ideas, exchange questions and beliefs, and consequently, they will be actively engaged.

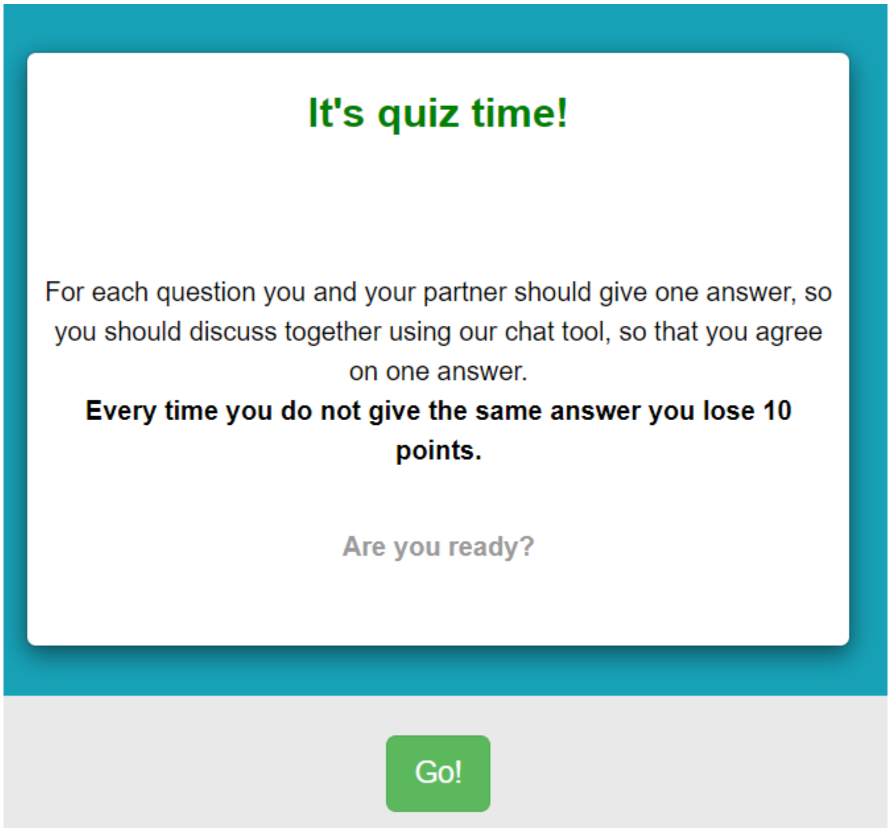

Figure 16: The message shown before the quiz, which explains the rule of the collaborative quiz

When a student chooses an answer, the system will compare it with the partner's answer and return feedback according to these three cases: First, his/her partner has not responded yet, the system will ask her/him to wait for his/her partner's response (Figure 17). Second, he/she did not give the same answer as the partner's answer, the system will warn that he/she and his/her partner don't agree on the same answer, and they have lost 10 points. It will also ask her/him to discuss more with their partner using the implemented chat tool (see Figure 19). In the third case, the two partners agree on the same answer, so their collaboration was successful (Figure 18).

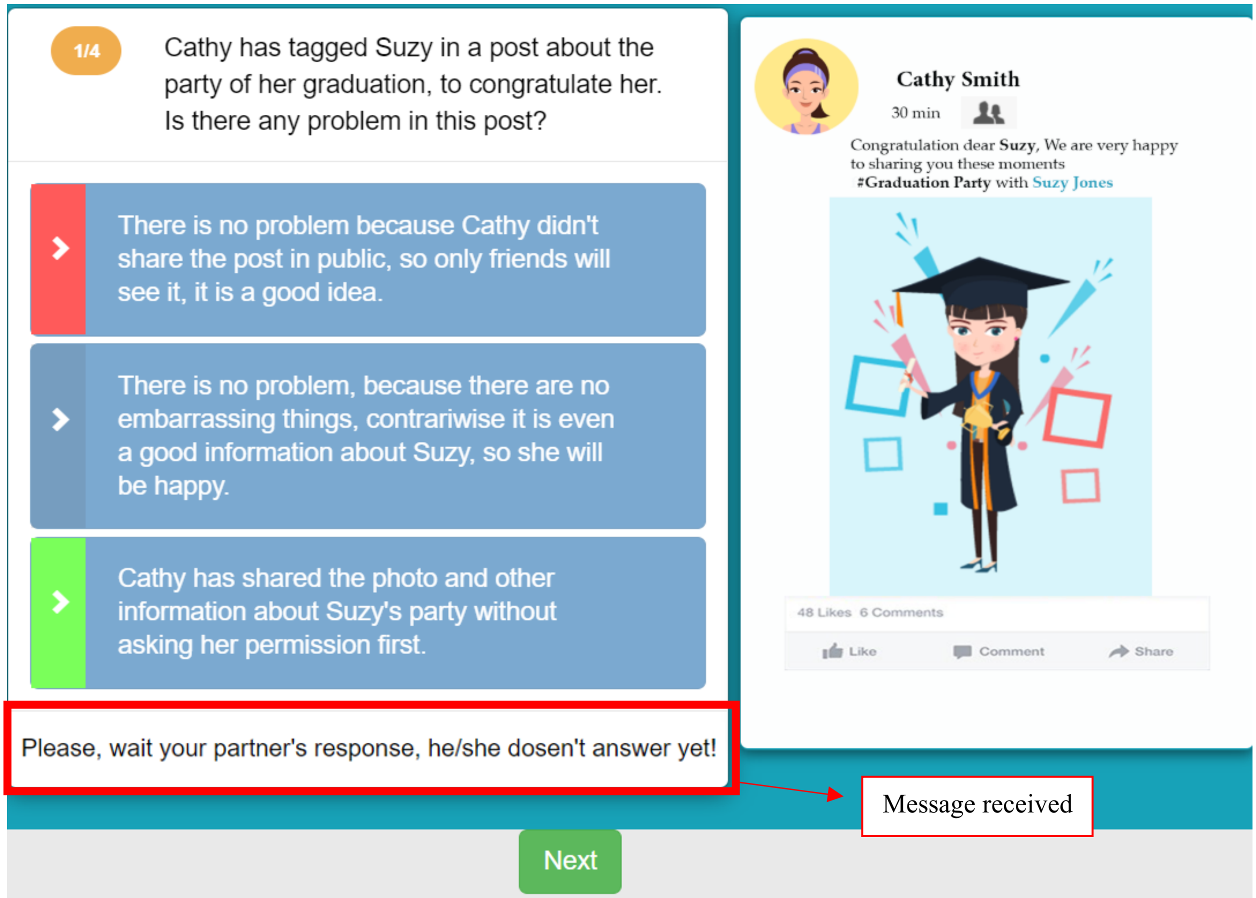

Figure 17: Example of the message received when the second partner has not responded yet.

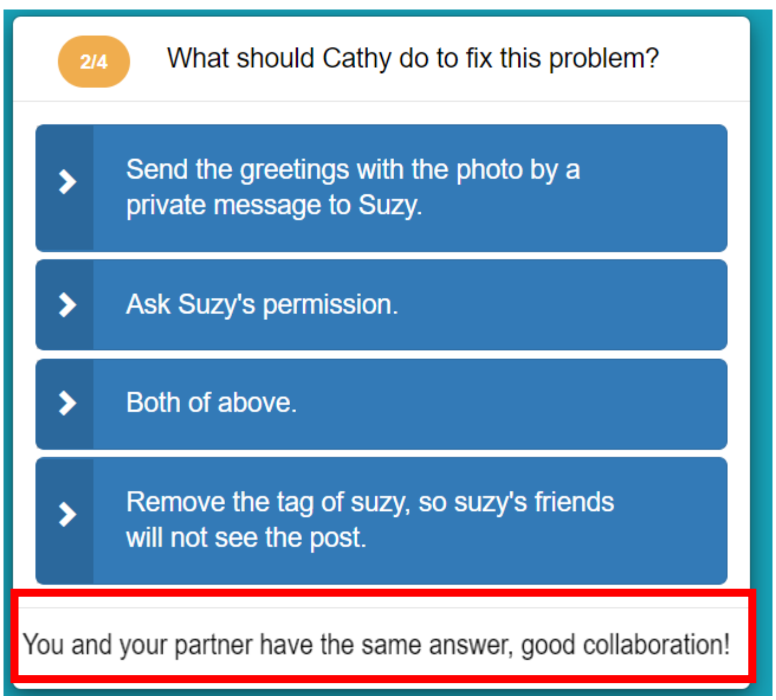

Figure 18: Example of the message received in case of the two partners agree with the same answer.

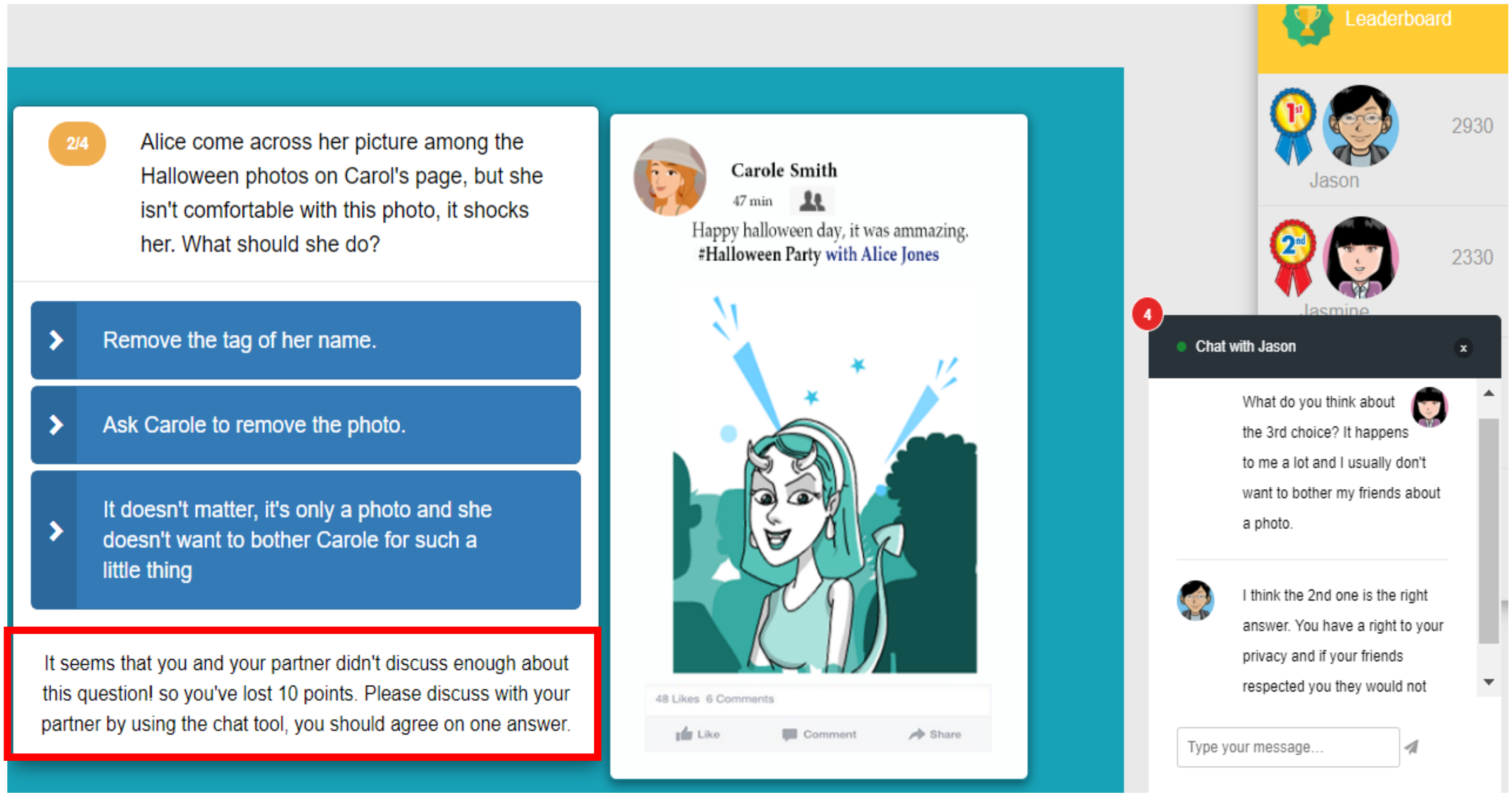

Figure 19: Example of the message received when a student did not provide the same answer as their partner.

In order to allow students to discuss together, we provide private and public discussions (Bull *et al*., 2001). We implemented a chat tool as a private discussion tool, to support the discussion among students via text. The chat tool allows a student to communicate only with his/her partners as a one-on-one interaction. Furthermore, we provided a public discussion forum that is open to everyone. This discussion forum allows all students to discuss and share their experiences, stories and/or questions about privacy. This page is divided by three essential issues on privacy: cyberbullying, identity theft, and the right to privacy. Figure 20 shows a screenshot of the discussion forum and how students can discuss and share experiences about privacy issues.

All the mechanisms in this module provide the student with an environment that allows her/him to see situations from other perspectives and learn by listening to diverse viewpoints from people with varied backgrounds. Moreover, students are also allowed to express and defend their ideas. This added value is essential in many educational environments as it enables the exchange of knowledge among students when solving quizzes, and ensures learning is not only dependent on the expert's context (Halavais, 2016).

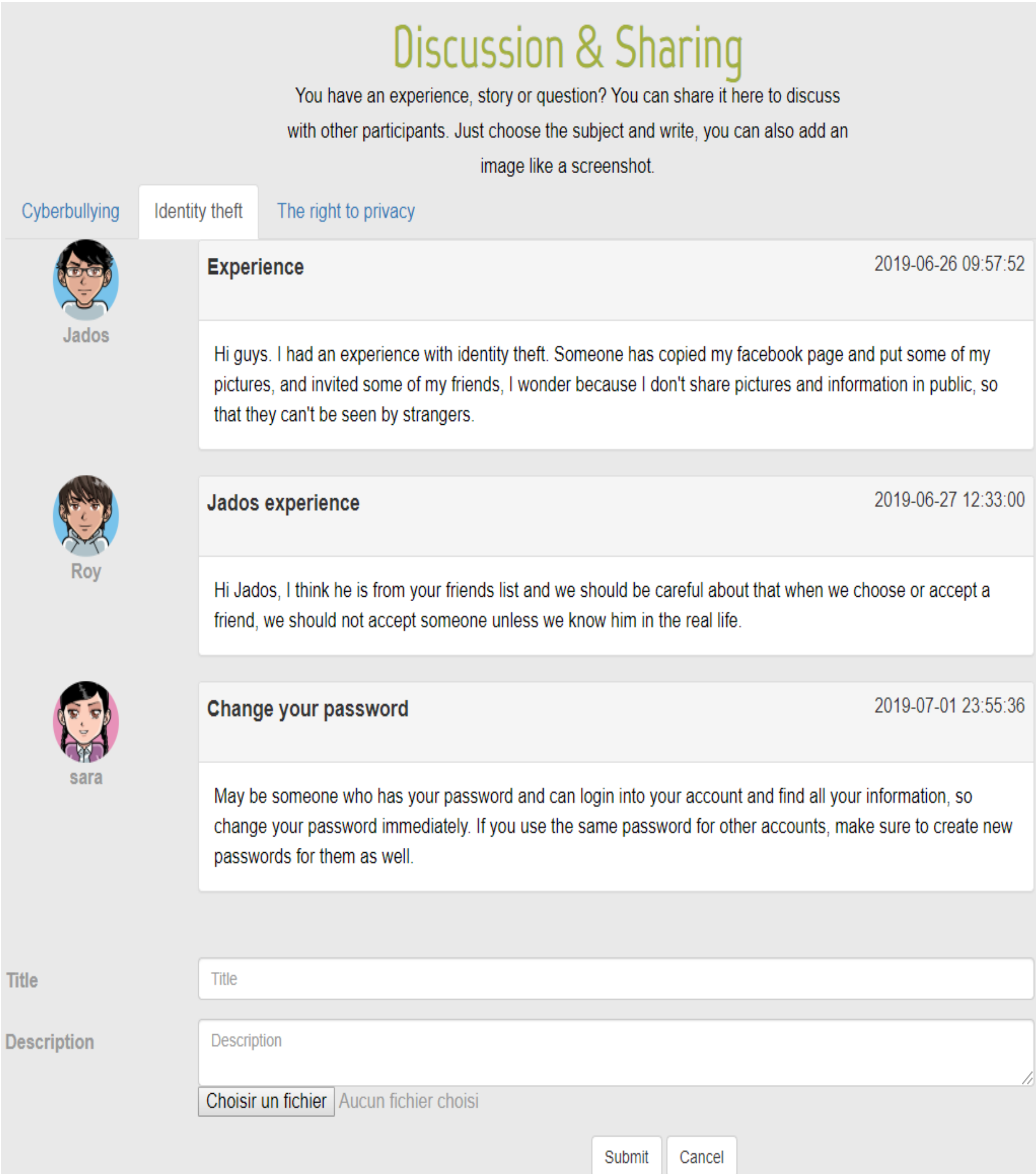

Figure 20: Screenshot of the discussion forum, the page on "identity theft"

3.2.3. The Domain Model

This model is responsible for organizing the privacy courses, which are divided into modules and topics. It can be considered storage, where the materials are kept, and use what we want if needed. It contains all the materials that we designed in Section 3.1, including modules, topics, videos, quiz questions, feedback, answers, and scores associated with each answer.

3.2.4. The Tutor Model

This model acts as a controller that coordinates between the student model and the domain model, providing a student with topics according to the acquired knowledge in the student's model. In other words, it does not transfer a student to the next topic unless he/she has passed the quiz in the present topic with an average of more than 60% (passing grade). Otherwise, the student will need to repeat the current topic to better understand it (Figure 21). Also, it registers the completed topics in the student model, as well all the student answers, and coordinates with her/his partner (as we have seen in the section 3.2.2, collaborative environment). Moreover, it gives suitable feedback at the level of answers and collaborative work.

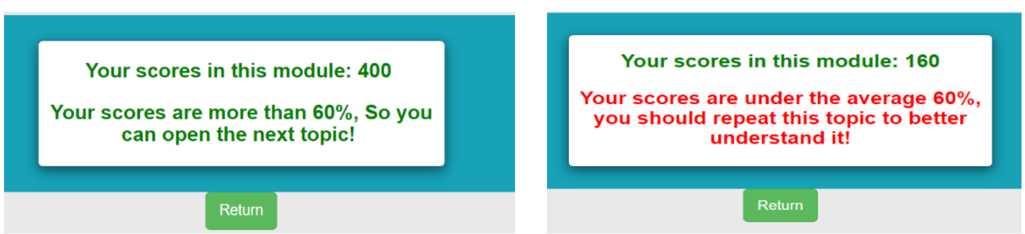

Figure 21: Messages received after the quiz to inform student about her/his results.

It manages the matching game processes in order to choose a perfect partner for each student, so it will allow the student to choose his/her preferences, as well as evaluate the behavior of her/his partner and register it in the student model. In other words, the tutor model can be considered the manager of the functionality of the entire system.

3.2.5. The Student Model

Greer and McCalla (2013) described the student model as an abstract representation of the student in the system. This model represents the student in the system, so it contains all the information that helps the tutor act adaptively to the student. In the proposed platform, the student model includes the student's login information, name, avatar, age, and gender. It also represents the current state of the student and his/her progress so that the tutor can know what knowledge was acquired by consulting the topics completed in the student profile, as well as their scores and answers. This helps the system compare the student's answers with his/her partner's answers (as we saw in Section 3.2.2). Also, the student's preference list of friends and his/her perfect partner chosen by the system will be stored in his/her profile, together with all discussion and chat information.

Moreover, each student has a knowledge profile that is initialized first by a pre-test[19] once he/she creates an account in the platform. During the pre-test, the student answers questions about the main concepts of our courses. These main concepts are: (1) privacy; (2) security; (3) technical aspects; (4) economical aspects; and (5) regulations and legislation. As a result of this pre-test, the student has a topic-specific knowledge profile that is changed adaptively when the student goes through the courses and completes quizzes. The topic-specific knowledge level is changed according to quiz results and the course subject.

3.2.6. User Interface

The interface in the proposed platform has two parts, one for the student and the other for the administrator or teacher. The admin page allows the administrator to see information about students, block and activate students, participate in and delete messages from the discussion forum, see all of the preference lists of students, execute the proposed matching algorithm, and manage the selection stages. The student's page allows a student to browse the courses, watch the videos, take the quizzes, discuss with his/her partner(s) using the provided chat tool,

[19] See the pre-test in the appendix

participate in the discussion forum, and rank his/her preferences of friends in order to create a preference list and evaluate the behavior of his/her partner(s).

3.2.7. Learning Style

Learning style is the method that learners should adopt for treating and interacting with information (Jafari & Abdollahzade, 2019). Since the proposed platform is basically designed for teenagers, we should consider the learning style that corresponds to this generation. In general, the younger generation have a large capacity for storing pictures in long term memory (Almeida & Almeida, 2016). The most practical strategies for them tend to be visual elements, graphics, storytelling (Wolfe, 2001), short videos (Almeida & Almeida, 2016), small learning units, and short-term activities (MacNeill, 2018). Moreover, to provide motivation and challenge in an e-learning environment, research has shown that using game mechanics in the learning environment makes it more interesting and increases students' interactivity and engagement (Bouchrika *et al*., 2019). To fit all these learning preferences for this age group, two essential methods were adopted to build our proposed platform: microlearning and gamification. The following subsections discuss the two adopted methods.

a. Microlearning

Microlearning is an approach that consists of micro-content delivery and a sequence of micro-interactions. This approach enables students to learn without information overload, while simultaneously helping them to retain the content in their memories (Bruck *et al*., 2012).

To apply this approach, we have converted the learning outcomes into smaller topics. Each topic talks about one concept that allows a student to go over it within 10-15 minutes. Also, the topic consists of one micro-video, which presents only meaningful and focused content, and one short quiz with feedback. The micro-videos provide quick and focused information, considered to be knowledge acquisition, whereas the short quizzes are skills acquisition.

Moreover, a student cannot access the next topic until they successfully complete the current topic with a grade above 60%. This, in turn, guarantees that a student cannot start a new topic without completing the prerequisite topics.

b. Gamification

Gamification is defined as the inclusion of game-like features in non-game contexts (Schöbel *et al*., 2019). Gamification is defined also as a type of persuasive technology (Chalco *et al*., 2015) that leverages the persuasive power of games to cause positive behavior changes in people. Recently, Greer's researchers Orji, Greer, *et al*. (2019) showed the importance of persuasive technology that is designed to change attitudes or behaviors and to motivate students to engage more in learning activities. Moreover, persuasive strategies such as rewards, competition, social comparison, and social learning, motivate students' learning and lead to success in the education domain (Orji, Oyibo, *et al*., 2019).

Motivated by the above-mentioned facts, the following game design elements are implemented in our platform: points, badges, leaderboard, avatars, and teammates (Baba *et al*., 2018; Hsieh & Yang, 2019; Sailer *et al*., 2017) for the purpose of engaging students, motivating action, upgrading learning, and solving problems.

Points. The points system is a basic element in a gamified application that shows the student's progress but in numerical form. In our platform, a student receives points when he/she answers the quiz's questions. Thus, if a student answers a question correctly, he/she will gain the complete points (e.g 100 points). In the proposed platform, we have assigned a weight for each answer because some answers might be partially correct. However, students can lose some points when they do not work as a team. This strategy encourages students to collaborate with each other.

Badges. In a gamified system, badges are the visual representations of a student's achievements. So, the student can be rewarded with a badge when he/she completes a certain set of activities (Sailer *et al*., 2017). In the proposed platform, we have associated each module with a badge, so we have designed a special badge for each module. Figure 23 shows the badges earned for the first three modules. Moreover, we assigned three leader badges as rewards to those students who obtained the highest scores.

Leaderboard. A leaderboard is the most basic element of competition in many videogames, usually ranking all players according to their progress. This mechanic creates a competition among students in order to obtain higher ranking through completing more topics. In fact, the leaderboard is considered an important resource of motivation for competitive students. However, one may ask what about low-performance students? This mechanism can be detrimental and harmful for them, negatively affecting their interest and engagement, known as "Undesired Competition" (Andrade *et al.*, 2016). To address this problem, we opted to include only the highest scoring students (e.g., the best five students) in the leaderboard (see Figure 23).

Avatars. Avatars are visual representations of players during the game. In gamified e-learning systems, designing and picking the right avatar has the ability to create a strong emotional connection between the learner and the gamified interaction, thereby significantly improving the level of engagement (Werbach & Hunter, 2015). In the proposed platform, when a student signs up, after filling out all related information, the system will display the list of avatars that matches his/her gender. A student should choose one avatar to represent herself/himself, and also choose a pseudonym that will appear to other participants (Figure 22).

Figure 22: One of these two windows will appear according to the student's gender, which allows him/her to choose his/her avatar and pseudonym.

Teammates. Teammates are essential elements in videogames, whether they are real players or virtual characters. This can promote cooperation among students in order to achieve a shared objective (Sailer *et al.*, 2017). In the proposed platform, we have applied teammates when we provide a collaborative environment by allowing students to work, discuss and solve quizzes with each other as they have same objective. In fact, this is the core of our platform, since collaboration between peers is one of our objectives.

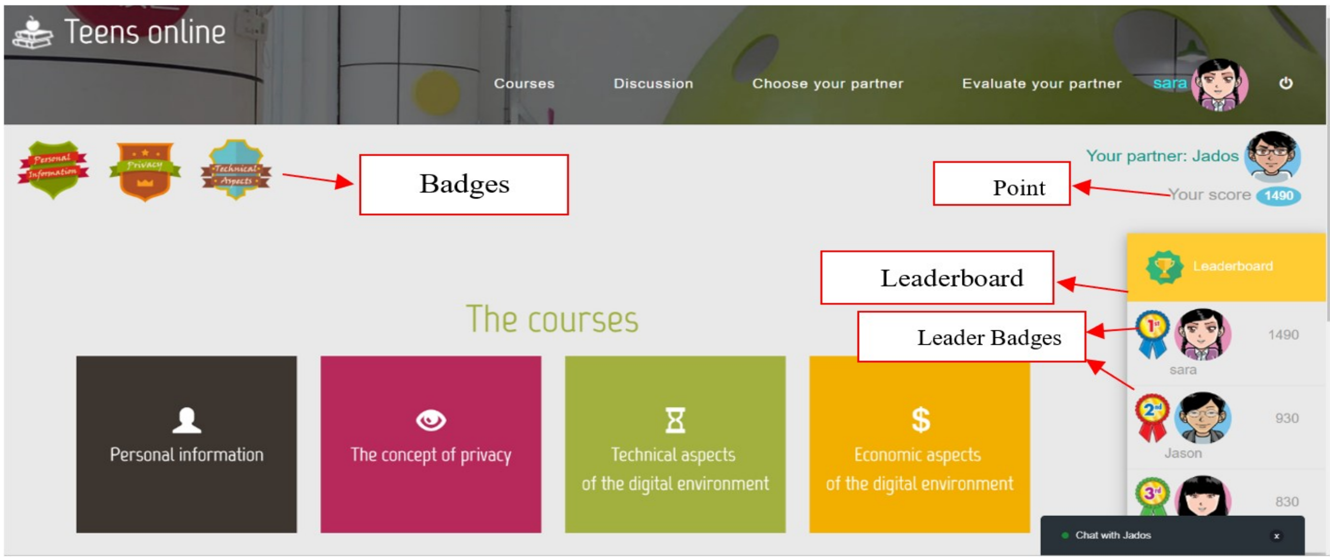

Figure 23: Student interface-courses page, shows the elements of gamification: points, badges, and leaderboard.

3.3. Implementation

The implementation phase is the process of moving the project from concept to reality, to give us the actual project result. More specifically, since "Teens-Online" is a dynamic web-based system, we used the following web technologies:

- PHP is one of the most used programming languages in the world and designed specifically for the web. We have used it for the server-side dynamic scripting.
- MySQL for managing the database. Students' profiles (including knowledge profiles, behavioral history, discussions, etc.) and the domain model (including courses and quizzes) are available under MySQL. The information stored there is easily accessible using Structured Query Language (SQL) commands.

- JavaScript for client-side scripting, which manages the portion of the display to show the visual elements.
- AJAX to exchange data from/to the server-side and the client-side. With AJAX, the system sends data to the database management system and manages the reception of the results.

The above-mentioned technologies are designed to work together, in order to realize our platform. The functionality of all components in this platform has been tested.

Chapter 4 – Experimental Evaluation

In this section, we designed a proof-of-concept experiment. The main goal of our experiment was to study the quality of students' partners that were assigned according to the proposed matching algorithm, and also to see to what extent the proposed partner matching algorithm could enhance students' satisfaction in a collaborative learning environment. The output of this study would suggest the importance of assigning "suitable" partners in improving educational outcomes.

4.1. Experimental Setup

In the implemented partner matching algorithm (GTPS), as we have seen in Section 3.2.1, each student can rank other students (anonymously) according to his/her behavioral qualities and preferences as well as according to their knowledge needs, so that each student builds his/her preference list. In this experiment, we considered two groups: A and B. Each group contained 10 students. Thus, the total number of students was 20. Each student's profile had their scores in 12 identified qualities, which are used as matching criteria. These qualities were classified into two categories. The first category consists of *knowledge qualities* that represent student levels on the main course concepts, namely privacy, security, technical aspects, economical aspects, and regulation. The second category consists of *behavioral qualities*, which includes seven personality traits considered essential to improve collaborative work and students' success (Meador, 2019). These qualities are conscientiousness, gregariousness, independence, intuitiveness, kindness, passionate, and respectfulness.

To execute the proposed partner selection algorithm, we should have the preference lists for all students. In this experiment, the preference lists were built by determining specific characteristics as preferences for each student. Based on these preferences, we have built the preference lists to measure to what extent the proposed partner matching algorithm could fit students' preferences and result in their being satisfied.

To build the preference list for each student, we considered the fact that each student had his/her individual characteristic preferences, so that each student considered different characteristics that he/she found important in partners when working together.

For example, in terms of knowledge, student *a* has a weakness in "security" and has a strength in "technical aspects", so she will prefer to collaborate with someone who is strong in "security", meanwhile student *b* who has a weakness in "technical aspects" will prefer to work with the student *a* who is strong in this topic. Therefore, each learner could help the other in one subject while benefiting from their help in the other subject. In terms of behavior, student *a* may like to collaborate with someone who is intuitive and conscientious, meanwhile, student *b* prefers to study with someone who is gregarious and respectful, and so on.

As a proof of concept, we chose 6 out of the 12 criteria for each student to use them as ranking factors. These six criteria are different for each student and contain both knowledge and behavior qualities. These qualities are ranked according to the student's preferences. To choose the preference list for each student according to her/his quality preferences, we adopt the fit score metric, which is inspired by the work of (Thanh *et al*., 2019) to perform multi-attribute rankings (Gratzl *et al*., 2013). The fit score for student *a* with student *b*, $fit_{(b \to a)}$ means how student *b*'s qualities fit student *a*'s preferences, so that it reflects to what extent student *a* was able to meet the needs or preferences in student *b*.

To choose the preference list for each student *a* from group A according to her/his quality preferences, we calculate the fit score for student *a* with each student in group B. This calculation takes into account the factors' weight, which indicates the significance level of each quality in student *a*'s preferences. The calculation of $fit_{(b \to a)}$ score is formulated as follow:

$$fit_{(b \to a)} = \sum_{i=1}^{N} V_{Q_i b} \times W_{Q_i a} \qquad (2)$$

$$\mid \ 0 \leq W_{Q_i a} \leq 100 \ \wedge \sum_{i=1}^{N} W_{Q_i a} = 100$$

Where N is the number of qualities used as criteria, $V_{Q\,b}$ is student *b*'s values of a specific quality Q, and $W_{Q\,a}$ is the weight assigned to the quality Q and represents the importance of the quality Q in *a*'s preferences.

And to calculate the fit score for a student *b* from group B with each student in group A, the calculation of $fit_{(a \to b)}$ score is formulated as follow:

$$fit_{(a \to b)} = \sum_{i=1}^{N} V_{Q_i a} \times W_{Q_i b} \qquad (3)$$

$$\mid\ 0 \leq W_{Q_i b} \leq 100\ \wedge \sum_{i=1}^{N} W_{Q_i b} = 100$$

It should be noted that the weights assigned to the qualities are distributed in a decreasing way, whereas the highest weight reflects the most important quality (e.g. 25% for the first quality, 20% for the second, 15% for the third and fourth, 13% for the fifth, and 12% for the sixth) (Gratzl *et al.*, 2013).

For example, to build the preference list of student *a1* from group A, student *a1* ranked the qualities as (1) economical aspects; (2) gregariousness; (3) passionate; (4) technical aspects; (5) conscientiousness; and (6) independence, in descending order of importance. So, he will rank students in group B according of these preferences. To this end, the fit scores $fit_{(b \to a1)}$ for student *a1* with all students of group B are calculated, to see how each student *b*'s qualities fit *a1*'s preferences.

For example, to calculate the fit score for student *a1* with student *b1* (how *b1*'s qualities fit *a1*'s preferences), we apply the weights of *a1* qualities preferences on *b1*'s qualities values, which are: conscientiousness: 4/10, gregariousness: 5/10, independence: 9/10, intuitiveness: 10/10, kindness: 9/10, passionate: 3/10, respectfulness: 3/10, privacy: 3/10, security: 4/10, technical aspects: 9/10, economical aspects: 10/10, regulations: 7/10. And by using the equation (2):

$$fit_{(b1 \to a1)} = \sum_{i=1}^{N} V_{Q_i b1} \times W_{Q_i a1}$$

$$= \frac{(10 \times 25\% + 5 \times 20\% + 3 \times 15\% + 9 \times 15\% + 4 \times 13\% + 9 \times 12\%)}{10}$$

$$= 69\%$$

Therefore, by performing the same procedure we can calculate the fit score for *a1* with all students *b* in group B. Table 2 shows all of the calculated values.

Table 2: Fit scores for student a1 with all students of group B

fit* scores for *a1
$fit_{(b1 \to a1)}$ = **69.00%**
$fit_{(b2 \to a1)}$ = **53.90%**
$fit_{(b3 \to a1)}$ = **70.70%**
$fit_{(b4 \to a1)}$ = **71.10%**
$fit_{(b5 \to a1)}$ = **54.10%**
$fit_{(b6 \to a1)}$ = **64.90%**
$fit_{(b7 \to a1)}$ = **52.90%**
$fit_{(b8 \to a1)}$ = **69.70%**
$fit_{(b9 \to a1)}$ = **82.50%**
$fit_{(b10 \to a1)}$ = **63.70%**

4.2. Experimental Results:

According to the values of fit scores, student *a*1 from group A creates his preference list by ranking the students of group B from the highest to the lowest values as follows: [*b9, b4, b3, b8, b1, b10, b6, b5, b2, b7*].

Therefore, by executing the same procedure, for all students *a* from group A and for all students *b* from group B, preference lists for all students are created. Table 3 shows the ranking matrix of students from group A and students from group B. In this matrix, the first number of each pair gives the ranking of students in group A by students of group B. The second number is the ranking of students in group B by students of group A. Thus, *b1* ranks *a3* first, *a9* second, *a1* third, and so on; a1 ranks *b9* first, *b4* second, *b3* third, and so on.

Table 3: The ranking matrix of students from group A and students from group B

	a1	*a2*	*a3*	*a4*	*a5*	*a6*	*a7*	*a8*	*a9*	*a10*
b1	3,5	7,7	1,4	4,10	10,8	6,4	9,7	5,5	2,2	8,7
b2	9,9	1,1	10,9	4,6	5,7	7,9	2,3	8,1	3,10	6,6
b3	9,3	8,9	6,7	3,4	5,9	2,3	10,10	4,7	1,7	7,9
b4	10,2	3,2	9,6	2,1	4,2	8,5	1,2	7,2	6,3	5,5
b5	10,8	6,5	7,8	3,3	2,6	4,10	8,5	9,9	1,4	5,4
b6	6,6	9,6	5,10	3,3	7,4	1,2	10,9	4,8	2,5	8,8
b7	6,10	2,4	8,1	3,7	7,5	5,6	10,6	9,6	4,9	1,3
b8	2,4	6,10	5,5	3,8	9,10	4,7	8,8	7,4	1,6	10,10
b9	7,1	4,3	10,3	1,2	3,1	6,1	8,1	9,3	5,1	2,2
b10	7,7	2,8	9,2	3,9	5,3	8,8	10,4	6,10	4,8	1,1

By applying the proposed partner matching algorithm (GTPS) on students' preference, we obtained the matched pairs as output. The highlighted boxes in Table 3 are the results of the chosen partners by applying the proposed matching algorithm. Thus, *a1* matched with *b3*, *a2* matched with *b2, a3* with *b1*, and so on.

In Table 3, we see that *a1* can find another partner who fits his preferences better than *b3* (such as *b4*), but if we verify the preference list of *b4* we notice that *a1* doesn't fit *b4*'s preferences better than his current partner. Since the collaborative learning will not work if a match only satisfies one party, it is essential to take into account the preferences of both partners. Although the algorithm does not always give each student the ideal partner, it guarantees that there does not exist any pair (a, b) where both would prefer each other to their current matched partner. This is due to the stability of the proposed algorithm, which is based on a stable matching algorithm (Gale & Shapley, 2013). Therefore, we can say that the proposed partner matching algorithm respects the reciprocal benefits of each pair.

In order to demonstrate that the proposed partner matching algorithm respects the reciprocal desires of the students, and to show the visual analysis of multi-attribute rankings (Gratzl *et al.*, 2013), the fit scores of each pair are calculated with the decomposition of the score components and represented in bar charts.

Figure 24 demonstrates an inline horizontal stacked bar chart to visualize how compatible each student is with their partner, and to what extent each of the two partners' characteristics suits the preferences of others. Moreover, it shows the fit scores with decomposition of the score components.

Qualities are color-coded and they are different for each student because they represent the partner's preferences and the length of each portion represents the student quality's score. The order of colored bars is based on how the student's partner ranked the importance of the characteristics.

To illustrate, in Figure 24, user *a1* ranked the characteristics as economical aspects, gregariousness, passionate, technical aspects, conscientiousness, and independence in descending order of importance. Therefore, stacked bars beside *b3* (*a1*'s partner) are arranged consistently in this order, the length of each portion represents *b3*'s scores at these characteristics, and the score beside it is the fit score of *a1* with *b3 (it is 70.70%).*

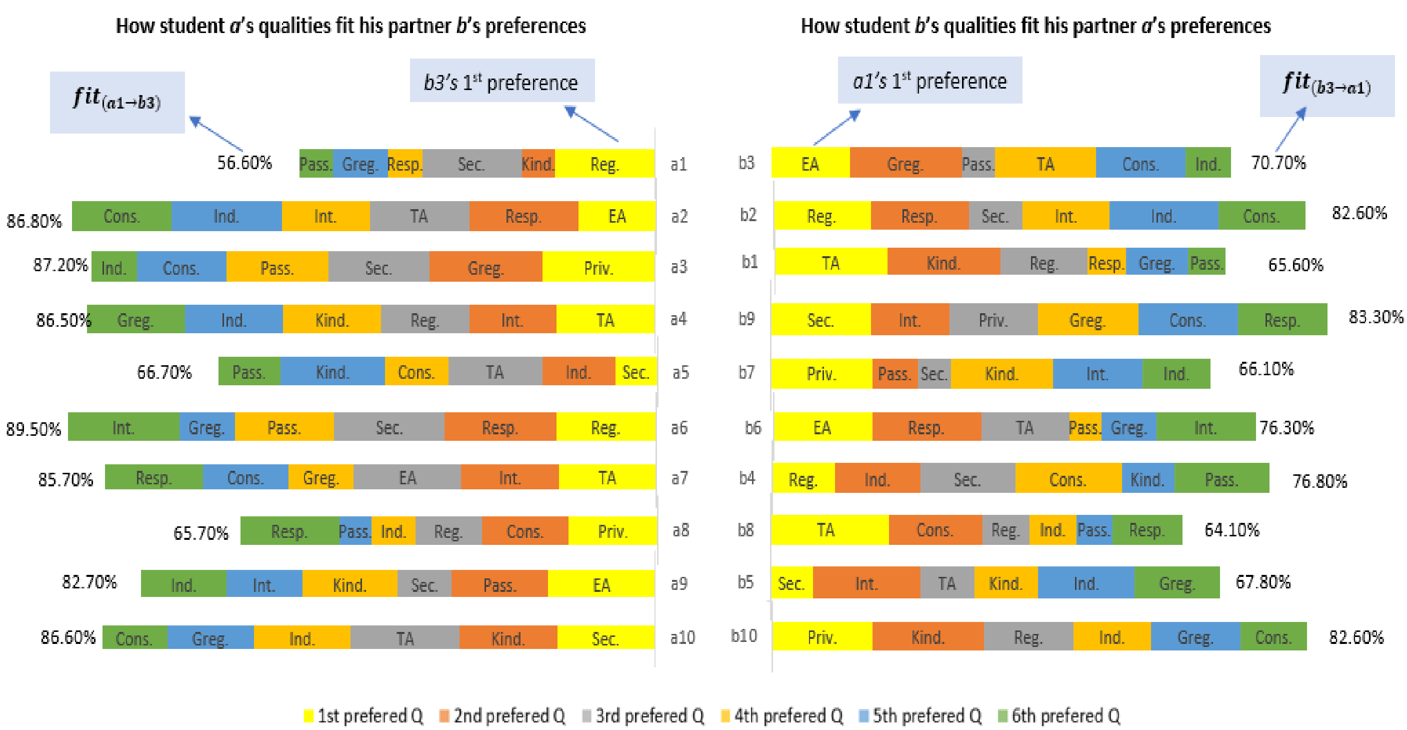

Figure 24: Inline horizontal stacked bar chart of fit scores with decomposition of the score component

The GTPS algorithm was compared with three other methods: preference-based and characteristics-based homogeneous clustering methods (Pang *et al*., 2014; Zakrzewska, 2009). Our method was also compared with the Random-based Matching method (RM). In fact, the random method was considered because it is known as the typical educator's choice and it implements one of the grouping strategies most widely used by teachers in their classrooms, in order to mix all students together and achieve heterogeneity within groups (Dascalu *et al*., 2014; Y. Zheng *et al*., 2018). The RM is also used as a competing method by other researchers (Moreno *et al*., 2012; Pang *et al*., 2014; V. Yannibelli & Amandi, 2012; Y. Zheng *et al*., 2018; Z. Zheng & Pinkwart, 2014).

In previous research, different clustering algorithms have been used to solve the learning group formation problem, in order to group students that prefer similar styles, or have the same goals, or the same personality and interests. (Bekele, 2006; Cocea & Magoulas, 2012; Pang *et al*., 2014; Zakrzewska, 2009).

In this experiment, Preference-based Homogeneous Clustering Method (PCM) was used to pair together students with the most similar preferences, whereas in the Characteristics-based Homogeneous Clustering Method (CCM), students with the most similar characteristics are paired together.

Table 4 shows a comparison between the four methods regarding the fit scores obtained for each student with their partner. We observe that the proposed partner matching algorithm can give students a higher percentage of desired qualities, compared to the RM, CCM and PCM. This is due to the fact that the proposed partner matching algorithm considers students' desires and performs the matching processes according to their preferences.

Table 4: The fit scores obtained for each student with their partner, in each of the four methods (RM, CCM, PCM and GTPS algorithm)

	RM	**CCM**	**PCM**	**GTPS**
A1	54.10%	56.80%	54.10%	**70.70%**
A2	65.10%	54.90%	65.10%	**82.60%**
A3	**68.70%**	54.80%	62.60%	65.60%
A4	50.80%	61.00%	63.20%	**83.30%**
A5	46.90%	54.10%	56.80%	**66.10%**
A6	66.60%	47.00%	54.90%	**76.30%**
A7	64.00%	61.70%	45.00%	**76.80%**
A8	**70.50%**	62.60%	69.80%	64.10%
A9	60.70%	**77.00%**	60.70%	67.80%
A10	48.10%	**82.60%**	81.50%	**82.60%**
B1	72.50%	55.20%	54.70%	**87.20%**
B2	62.80%	62.10%	65.00%	**86.80%**
B3	**68.60%**	57.10%	47.10%	56.60%
B4	59.20%	78.60%	66.70%	**85.70%**
B5	55.20%	54.70%	55.20%	**82.70%**
B6	59.90%	65.00%	59.90%	**89.50%**
B7	56.70%	57.60%	**76.20%**	66.70%
B8	48.90%	59.80%	**73.40%**	65.70%
B9	44.70%	73.20%	85.80%	**86.50%**
B10	73.70%	**86.60%**	73.70%	**86.60%**
COMPATIBILITY SCORE	59.89%	63.12%	63.57%	**76.50%**
AVG OF COMPAT. SCORE IN 5 TIMES	61.53%	63.90%	64.62%	**74.20%**

In Table 4, we can observe that in some cases a student can obtain a higher fit score with the other methods than with the proposed algorithm. For example in RM, *a3* has 68.70% with his partner *b9* (in the random match) and has 65.60% with his partner *b1* (in the GTPS algorithm). However, if we verify *a3'*s quality preferences, she ranks them as (1) technical aspects; (2) kindness; (3) regulations; (4) respectfulness; (5) gregariousness; then (6) passionate, in descending order of importance. In comparing the *b9* and *b1* profiles in Table 5, we see that *b1* (*a3*'s proposed partner by GTPS algorithm) satisfies the four most important qualities of *a3,* where *b1's* score values in these qualities are higher than *b9's*. On the other hand, the GTPS algorithm considers the reciprocal benefit of both partners, so we observe that the benefits given by *a3* to his proposed partner by the GTPS algorithm *b1* (*87.20%*) are higher than those given to his partner *b9 (44.70%)* by the random-based matching.

Table 5: Comparison between b1 and b9's score values with a3's preferences. b1 is a3's partner in GTPS algorithm, b9 is a3's partner in RM

	Behavior qualities							Knowledge qualities				
	Conscientiousness	Gregariousness	Independence	Intuitiveness	Kindness	Passionate	Respectfulness	Privacy	Security	Technical. Aspects	Economical Aspects	Regulation
a3's preferences		5th			2nd	6th	4th			1st		3rd
b1	4	5	9	10	9	3	3	3	4	9	10	7
b9	9	9	9	7	9	10	8	8	9	3	9	5

To generalize the results, the compatibility score was calculated by taking the average of all the fit scores for each method. By comparing the compatibility scores, we found that the proposed GTPS algorithm has a higher utility (76.50%) compared to the CCM (63.12%), the PCM (63.57%), and RM (59.89%). These results suggest that students will be more satisfied with their partners when applying the proposed partner matching algorithm than applying other matching methods.

Each method was run five times for the same set of students, with changes to the quality preferences for each student each time. The average of the compatibility scores was calculated for each method (shown in Table 4), and the result obtained by the GTPS algorithm (74.20%) was still higher than the result obtained by the other methods. Our results reflect the satisfaction of each student with their partner according to her/his preferences.

Although further experimentation is required in order to get more information about the influence of the proposed matching algorithm on individual learning outcomes, the results obtained suggest the possibility of considering the approach of the partner matching algorithm for different collaborative platforms.

Furthermore, the partner selection mechanism can be improved by carrying out the ranking procedure automatically by the system (instead of by the student) in order to accommodate larger numbers of students. In this case, students can only rank the behavior qualities according to his/her preferences and register it in his/her profile, and the system then creates the preference lists according to students' behavior preferences as well according to students' knowledge profiles. This procedure can be considered as a future work, and can be implemented in the proposed platform.

Chapter 5 – Conclusion and Future Work

The main objective of this research was to provide a collaborative e-learning platform on privacy awareness, equipped with a stable partner selection mechanism. More specifically, the following objectives were attained:

- Proposing a well-structured curriculum that covers the necessary concepts of privacy. In Section 3.1 we presented the steps of our methodology to achieve this objective. With these steps, we explained how we designed our courses based on the Personal Data Protection Competency Framework for School Students (PDPCFSS). We also created the micro-courses that contain micro-videos and short quizzes in order to build a micro-learning system that corresponds to the learning styles of teens.
- Designing and implementing an e-learning platform that presents the courses using modern teen-related learning styles. For this purpose, we designed an architecture that shows the structure of our platform and its elements (presented in Section 3.2). Following that, a web-based platform was implemented in order to provide students with an e-learning system using modern teen-related learning methods, such as microlearning and gamification.
- Providing a collaborative environment that allows students to share ideas while learning. In Section 3.2.2, we presented a collaborative environment that enables students to solve quizzes together as a team and allows them to discuss and interact. In fact, we adopted this approach because it had proven to be an effective method in traditional classrooms. In this research, we show that this approach can be applied in online classrooms. We have successfully designed and implemented this approach in our platform.
- Perform a stable matching between students in order to find the perfect partners for each student, based on his/her preferences. In Section 3.2.1.a, we presented a partner selection mechanism that adopts a stable matching algorithm, based on matching game theory. More specifically, we adopt a “stable marriage algorithm” (Gale and Shapley algorithm) to make an optimal student-student match according to the student’s knowledge profile. We have successfully implemented and tested the proposed algorithm and numerical results show the effectiveness of the proposed algorithm compared to other partner selection methods.

- Improving the selection of partners and also the interaction between students, to prevent the problems caused by working with non-appropriate partners. To this end, we integrated the history of partners' interactions into the proposed matching game algorithm. In Section 3.2.1.b, we explained how we allow each student to evaluate partners' interaction and behavior, in order to have a behavior history for each student. In Section 3.2.1.c, we demonstrated how to apply the proposed matching game algorithm (partner selection algorithm) based on the behavior history and knowledge profile. This mechanism is performed anonymously in order to guarantee that the selection is based only on students' quality (behavior and knowledge), not on their identity. At the same time, this process should be done anonymously for the purpose of privacy, to prevent the intimidation of students. This strategy allows students to improve their selections and at the same time their interactions with their partners.

In summary, this work presents a collaborative e-learning platform on privacy awareness "Teens-Online". The proposed platform enables teenagers to acquire the necessary knowledge on privacy, and at the same time, share ideas amongst themselves. Moreover, to avoid all the problems of collaborative environments and in order to choose the right partners for each student, this work proposes a partner selection mechanism based on Game Theory (GTPS). This mechanism provides a stable student-student matching according to students' preferences regarding knowledge needs, as well as according to students' behavior. This mechanism can help us to improve the selection as well as enhance students' interaction.

The following points summarize the main contributions of this thesis. First, the design of a curriculum on privacy awareness for teenagers, by following our methodological steps. With these steps, our courses were designed based on the Personal Data Protection Competency Framework for School Students (PDPCFSS). These courses are divided into micro-courses that contain micro-videos and short quizzes, in order to build a micro-learning system that corresponds to the teens' learning style. Moreover, the proposed platform provides a collaborative environment that allows students to share ideas while learning and discuss and interact while solving collaborative quizzes. In addition, this work performs a stable matching between students in order to find the optimal partners for each student, based on his/her preferences in two categories: knowledge qualities and behavioral qualities. For this purpose, the GTPS algorithm is proposed to make an optimal student-student match. The knowledge characteristics are updated adaptively in the student's profile, whereas the behavioral history is updated by partners' evaluations. This mechanism allows students to improve their selections and learn from their experience, as well as from their colleagues' experience.

An experimental evaluation of GTPS used a satisfaction metric to determine to what extent the proposed partner matching algorithm can enhance students' satisfaction. The proposed algorithm was compared with other methods. Our results suggest that students will be more satisfied with their partners when applying the proposed partner matching algorithm than applying other matching methods.

As future work, the proposed matching algorithm could also be implemented as an addition to existing and widely used collaborative educational platforms, such as Edmodo and Moodle, with different courses materials (e.g. Mathematics, Physics, etc.). On the other hand, we are well aware that multiple dimensions should be considered in implementing this platform, such as the age of the students, their language and culture, as well as the learning situation (whether they are in their classroom or at home doing homework), mandatory or voluntary, etc. Furthermore, the partner selection mechanism can be improved by carrying out the ranking procedure automatically by the system (instead of by the student) to accommodate large numbers of students.

In terms of learning approaches, we are also aware that the solution we propose is a classical instructor-based approach, whereas we could have more student-based approaches, such as learning by discovery, by case study, or problem solving. This will be part of the further work that we envisage.

We are also considering, as future work, adding a chatbot as an assistant teacher to our platform. This teacher-bot can be used to teach the students by turning a course into a series of messages and multiple-choice questions. The bot could repeatedly evaluate the level of understanding of the student and provide the next part of the lesson accordingly. Also, as the student progresses, the bot could find related information from external sources, through a recommendation engine mechanism.

Appendix

Pre-test: is a knowledge assessment test, each student should pass this test once he/she creates an account in the platform in order to initialize his/her topic-specific knowledge profile. In this pre-test, the student answers some questions about the main concepts of our courses. These main concepts are: (1) privacy; (2) security; (3) technical aspects; (4) economical aspects; and (5) regulations and legislation. In the following table are the pre-test questions with their concepts (categories).

Categories	**Question**
• Privacy	1. Max has just finished his homework. He started his preferable game Boblox, it's an interesting online game with a chat champ, where he can find and meet many new friends. What should he do before starting to play? A. Use a nickname that contains his name to be recognized by his friends. **B. Use a nickname that does not reveal anything about him.** C. Use his real name to be more transparent. D. It's not a good idea to chat.
• Regulations and legislation	2. When playing with Boblox, there is unfortunately someone who follows him everywhere insulting him. What should he do? A. Disable the chat function. B. Take a screenshot and report his behavior to a moderator. C. Determine which guild he belongs to and report his behavior (if the game has a guild system). **D. Undertake all the above steps.**

• Security	3. During a chat session with a very nice girl, Max knows that she lives next door and they are almost neighbors. She offers him a meeting in person. What should he do? A. It's great to meet her. Max makes an appointment with this new friend. B. Before he makes an appointment with this new friend, he is looking for her name on social networks for more information. C. **Max makes an appointment with this new friend, after making sure that his older sister of 21 can accompany him.** D. He refuses. He must not meet a cyber friend in person.
• Privacy	4. While surfing Facebook, Max notices that a post from one of his friends is really rude. What should he do? A. Make an angry comment on his post. **B. Wait 'til tomorrow to talk to him about it in person.** C. Send a message to ask if his account has been hacked. D. Undertake all the above steps.
• Regulations and legislation • Privacy	5. By opening the Instagram application, Max sees a compromising photo of his new friend. This is a photo that was taken by her ex-boyfriend while they were dating. The latter was published in order to expose, ridicule, and embarrass her after their separation. In this case, the person who publishes: A. Is not guilty because he publishes a real photo without modification. **B. Is guilty and liable to imprisonment for a term not exceeding two years.** [20] C. Is guilty but without imprisonment.

[20] http://laws-lois.justice.gc.ca/fra/lois/C-46/page-72.html

https://needhelpnow.ca/app/fr/resources_did_you_know

• Technical aspects • Security	6. Max got a phone call from Carole asking him to meet at the Coffee Shop with their friends. At the Coffee Shop, he checks out the free Wi-Fi: 1. Coffee Shop Secure Network 2. Coffee Shop Official Wi-Fi 3. Advanced Secure Wi-Fi Coffee Shop A. Choose the Advanced network – it is the most secure. **B. Ask the cashier which network is the right one.** C. Choose any network from the list because all belong to the Coffee Shop
• Technical aspects • Security	7. After ordering a cup of tea, Carole uses the Coffee Shop's Wi-Fi to check the Radio-Canada website for the latest news at: https://ici.radio-canada.ca/info. Is this a safe activity? **A. Yes, it is safe.** B. No, it is not safe.
• Technical aspects • Security	8. Meanwhile, Jeremy tells his friends that his father's credit card information was recently stolen when he bought something online. Max interrupts to tell him that his father can ensure that their information is safe with some signs on the web page. What are these signs? **A. The site has a padlock icon in the address bar.** B. The site has a Cyber Secure seal of approval. **C. The site has a Web address that starts with "https".**
• Technical aspects • Security	9. Jeremy asks Max this question: What does the "https://" mean at the beginning of a URL, as opposed to "http://" (without the "s")? A. That the site has a special high definition. **B. That the information entered to the site is encrypted.** C. That the site is the latest version available. D. That the site is not accessible to certain computers. E. All of the above.

• Privacy	10. Jeremy asks again: If a website offers a privacy policy, does this mean that the personal information it collects about you is protected? A. True. **B. False.**
• Technical aspects • Economical aspects	11. This leads Carole to another question in her head: What are "cookies" used by many commercial sites? Max replies: A "cookie" is a file that is sent to your browser by a website you've visited to know the activities and pages viewed by visitors. From these statements about the cookies, which ones are true? A. Cookies can identify your email address. B. Cookies can search your hard drive for information and personal information. C. A computer virus can be hidden in a cookie and transmitted to your computer. **D. The cookies can track you on a site you visit and even know which advertisements you clicked on.**
• Security	12. Carole asks again: What does the phishing attack mean? Explain to me with an example. Which of the following examples is suitable? A. Sending someone an email that contains a malicious link that is disguised to look like an email from someone the person knows. B. Creating a fake website that looks nearly identical to a real website in order to trick users into entering their login information. C. Sending someone a text message that contains a malicious link that is disguised to look like a notification that the person has won a contest. D. **All of the above.**
• Security	13. Max forgets his laptop, so he did some online activities using a computer in the public library. Which activity is riskier? **A. Log into his account to check his emails.** B. Check some books and select what he needs.

	C. Search for a few shopping websites to write down their addresses. D. All of the above.
• Security	14. On leaving the library, Max finds a memory stick (USB) on the ground. What should he do? **A. Leave it there.** B. Take it home and use it. C. Format it and run a virus scan on it before using it.
• Privacy • Economical aspects	15. *"MusikEveryWhere"* is the official website of a popular TV show of rock music videos. Visitors are invited to enter a contest to win a prize. To register, Max must provide his name, first name, mailing address, age, telephone number, and email address as well as his answers to a quiz. What should he do? A. Because Max is a fan of the TV show, and knows the answer to the trivia question, he sees nothing wrong with entering the contest. **B. He prefers to read the contest rules and its privacy policy first.** C. Max does not participate.
• Privacy • Economical aspects	16. In the contest "*MusikEveryWhere*", after completing the quiz, Max is then prompted to provide the email address of his friends, to get more points or to increase his chances of winning. Thereafter, his friends will receive an invitation to participate in the contest. What should he do? A. Max feels confident because it is a known show, so after he has participated, he also gives his friend's e-mail addresses so they also take advantage of the contest. B. He prefers to read the contest rules and his privacy policy first. **C. He does not give the email address of his friends.**
• Economical aspects	17. While working, Max receives a message on his laptop that he has won a prize in a competition in which he participated. He decides to click on the message to get more information. Is it a safe choice? A. Yes, that's for sure.

	B. No, it is not sure.
• Economical aspects	18. Max has received an email from the online music store he uses often, offering him a free download of the long-awaited new album of his favorite band. What should he do? A. He downloads the album. **B. He goes to the site to know the details of the special offer.** C. He checks if anyone has already downloaded it to any file-sharing sites.
• Security	19. Max wants to change the password of his Gmail account. Which of the passwords below is the best? A. B@n@ne. **B. GB@nAn2L.** C. His mother's name.
• Technical aspects	20. On the way to school, Max forgets his phone on the bus! What should he do? A. He calls his number and makes an appointment with the person who found it to retrieve it. B. He gives up the idea of retrieving it. **C. As soon as you can, remotely disable your phone.**

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