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Step Towards a Model to Bridge the Gap between Personality Traits and Collaborative Learning Roles

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Abstract. This paper presents a model of relationship between personality traits and students' roles, based on learning theories, to improve the formation of high performance groups. It has two main contributions: first, a process to model collaborative learning roles based on personality traits; second, an ontological structure to support group formation. Regarding the proposed process, we defined four steps for an effective group formation: (i) determine personality traits characteristics; (ii) identify which personality traits characteristics may affect negatively students' behavior in educational collaborative settings; (iii) define new collaborative learning roles given the personality traits; and (iv) establish learning strategies to ensure students' educational benefits. Additionally, we represented those new roles in a collaborative ontological structure. Finally, we performed a case study, which showed evidences that unsociable characteristic may negatively influence students' behavior, and therefore, it should be considered to design CSCL scenarios and personalized systems to form high performance groups.

Keywords: CSCL, personality trait, learning theory, group formation, collaborative ontology.

1 Introduction

Computer Supported Collaborative Learning (CSCL) is a research area that investigates how technology can be used to support students' interaction and collaboration while promoting individual and group learning [1]. One of the challenges in this area is to define which factors (e.g. students' characteristics, individual/group goals, and pedagogical requirements) must be taken into account for establishing *high performance groups*. In educational settings, *high performance groups* are characterized by the synergy among group of students, which enables group goals to be thoroughly fulfilled as well as ensures improvements in learning of each student [3].

A literature review performed by Magnisalis et al. [35] shows that mostly of the studies explore group formation strategies relying on learners' profile (e.g., learning styles), tasks performed (e.g., amount of the activities, difficulty level) and/or adopted technology (e.g., artificial intelligence techniques). In this context, Isotani et al. [3] and Strijbos et al. [20] discuss the need of covering other factors in the process of group formation in order to design CSCL scenarios that support and increase the quality of learners' participation and interactions while working in groups.

Inaba and Mizoguchi [4] underline the importance of considering learners' roles in collaborative learning. This element can be a relevant resource to foment learners' awareness during interaction and collaboration with peers. Nevertheless, if the learner performs a role that does not suit his/her knowledge and skills, the expected educational benefits may not be achieved; and the whole collaborative activity may fail hindering the learning processes of other learners in the group. To avoid such a problem, instructional designers often use collaborative learning theories as a guideline to design collaborative learning activities [3, 4, 34]. These learning theories support the assignment of roles and can pedagogically justify learners' selection in group formation.

Other important factor considered in group formation is the personality trait. Chamorro-Premuzic and Furnham [8] and Andrei et al. [9] discuss its importance in students' academic performance and social interactions. They highlight this factor induces diverse students' actions and behaviors according to the circumstances (e.g., learning).

Regarding the use of personality traits in group formation [5, 6, 7, 12, 13, 15], we observed that they are generally used solely, i.e., without matching with other important factors to group students, such as learning theories, students' role, individual goals, among others. In addition, the grouping strategies adopted by these works do not offer a formalization that allows computational systems/environments to provide "smart" support for group formation in CSCL. In this context, we point out the importance of ontologies[1], which enable: 1) represent a domain with potential for reuse; 2) formalize a domain free of contradictions, ambiguities and inconsistencies; and 3) share the knowledge between people and/or computer applications [3, 32].

In this context, this paper aims at presenting a model (based on ontologies) to match personality traits (e.g., introvert, extrovert) to students' roles (e.g., anchored instructor, problem holder) referring to *collaborative learning roles* (CL roles), in order to improve instructional design of CSCL activities, specifically to create high performance groups. As main contributions, this paper provides: (1) a process that describes necessary steps to define new collaborative learning roles using personality traits (e.g., extrovert anchored instructor); and (2) an ontological structure to support group formation during the design of CSCL scenarios. Finally, we performed a case study in a real classroom setting to evaluate this approach. We believe this work

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[1] *Ontology* defines a set of concepts (classes and attributes) and their relationship to represent a specific knowledge domain.

contributes to the design of better CSCL scenarios and the creation of intelligent systems that can personalize group formation based on students' characteristics such as personality traits and students' roles.

This paper is organized in five sections: Section 2 presents a literature review about the use of personality traits in group formation in CSCL environments. Next, Section 3 describes the method to design the new CL roles and presents the ontology for group formation in CSCL. Section 4 shows a case study to evaluate the new CL roles. Finally, Section 5 reports the conclusions.

2 Literature Review

2.1 Group formation composition

One of the challenges in designing CSCL scenarios is selecting the factors that may affect the formation of high performance groups [3, 18]. Reis et al. [10] carried out a systematic mapping of the literature, which identified a fewer studies using personality traits combined with other important factors to personalize and support the group formation in CSCL environments. Most of studies have been investigating the impact of these combinations for the creation of homogeneous and heterogeneous learning groups. In this context, Graf and Bekele [19] presented a mathematical approach based on personality traits and students' performance to maximize groups' heterogeneity. In the same way, Wang et al. [12] designed a computer-supported heterogeneous grouping system to promote group interaction based on students' thinking styles. Additionally, Zheng and Pinkwart [15] proposed a computational algorithm based on personality traits and gender to compose heterogeneous learning groups. Using a different approach, Moreno et al. [16] presented a group formation method to get inter-homogeneous groups based on students' knowledge level, communication skill and leadership ability. Gogoulou et al. [13] proposed a tool, which can be used to form homogeneous, heterogeneous and mixed groups based on learners' personality and performance attributes (e.g. competence level). All these approaches have highlighted the importance of personality traits and their combination with other factors in order to support group formation in CSCL environments.

Despite the important contributions of those works to scientific community, we observed a lack of studies that used collaborative learning theories to support group formation matching students' learning roles (CL roles) and personality traits.

2.2 Group formation strategies

Considering that free collaboration among group members does not guarantee individual learning gains, researchers investigate grouping strategies that use personality trait to improve and personalize the formation of learning groups in CSCL environments. In this context, Farhangian et al. [11] and Shin-ike and Lima [14] presented simulation models based on agents and neural network to provide a prediction of students' knowledge acquisition and retention in collaborative learning. Other solutions introduce strategies based on genetic algorithms [12, 13, 16, 17], mathematical models [15, 19] and tools [12, 13, 17] to form learning groups.

Although there is a growing body of scientific knowledge that focuses on different grouping strategies, we observe that those solutions do not offer a formalization that allows their reuse and sharing. Thus, this work proposes the use of ontologies to represent the new CL roles that arise from relationship between personality traits and CL roles.

3 Modeling Personality Traits and their Relationships with CL Roles in the context of CL Scenarios

To model personality traits and their relationships with CL roles (defined by collaborative learning theories) in the context of collaborative learning, we employ ontology engineering techniques [28], the Hozo Ontology editor [32], and the model of CL roles proposed by Inaba and Mizoguchi [4]. Firstly, we identify the main concepts of collaborative learning theories and CL ontology (Section 3.1). After that, we establish the relationship between personality traits and CL roles (Section 3.2). Finally, in Section 3.3, we use ontological structures to formalize the concepts identified in the previous two sections (Section 3.1 and Sections 3.2) in order to provide computational support that considers personality traits in group formation and design of CL scenarios.

3.1 Collaborative Learning Theories and Collaborative Learning Ontology

In CSCL, many researches have studied and formalized concepts of collaborative learning theories in ontologies with the purpose of assisting group formation, instructional design of group activities and promotion of students' interaction [3, 34]. In group formation, collaborative learning theories are used to determine the *context* in which the learning activity will occur, the *kind of knowledge* and *skills* that will be developed, and the *role* that will be performed by learners. Some examples of collaborative learning theories are *Anchored Instruction* [21], *Cognitive Apprenticeship* [22], *Peer Tutoring* [36], among others.

Isotani et al. [34] emphasize the importance of a proper attribution of roles to students based on collaborative learning theories, which allows learners assume and adopt certain behavior to achieve the expected educational benefits when working in groups. In a seminal work in this direction, Inaba and Mizoguchi [4] discuss some students' behaviors related to thirteen CL roles, such as *peer tutor/peer tutee* [36], *master/apprentice* [22], and *anchored instructor/problem holder* [21]. An example of formalization created by Inaba and Mizoguchi [4] can be seen in Table 1, where the relationship among CL role, behavior, pre-requisite and expected educational benefits are based on Anchored Instruction learning theory [21].

Table 1. CL Roles, their pre-requisites, and their expected educational benefit for CL scenarios based on Anchored Instruction learning theory. (Source: [4]).

CL Role	Behavior	Prerequisites	Expected educational benefits
Anchored Instructor	A*dvising* to diagnose problems and give some advice to other learners.	* Having the knowledge. * Knowing how to diagnose others. - Not having experience in diagnosing others.	Acquisition of content specific knowledge (*tunning*). Development of cognitive skill (*associative stage*).
Problem Holder	P*resenting* to explain something in his/her mind to other learners.	* Having a problem. - Having the knowledge.	Acquisition of content specific knowledge (*tunning*).

Each CL role has a prescribed behavior defined by a collaborative learning theory. For example, a student who performs the *Anchored Instructor* role (column 1, Table 1) must adopt the behavior of *advising* (column 2) with the purpose of *diagnosing problems, advising and guiding* other students who perform the *Problem Holder* role. If a student plays the *Problem Holder* role (column 1), the behavior of *presenting* (column 2) must be used to *explain some content in his/her own words* to the student who performs the *Anchored Instructor* role. Beside the relationship between CL roles and the necessary behaviors to achieve educational benefits, Inaba and Mizoguchi [4] discuss the importance of identifying the pre-requisites (column 3), i.e. *necessary '*'* and *desired '-' conditions* to play a CL role. The *necessary conditions* are essential for a student to play a CL role. If the student does not satisfy these conditions, he/she cannot play the CL role appropriately. The *desired conditions* define prerequisites that students must satisfy to ensure the expected educational benefits. For example, according to the Anchored Instruction learning theory, a student can only play the Anchored Instructor role (necessary condition) if he/she: (1) has the knowledge about the content that will be covered, and (2) knows how to diagnose others learners, identifying their problems. On the other hand, to ensure educational benefits, in this example, it is desirable (desired conditions) that the student who will play the Anchored Instructor role: (3) does not have experience in diagnosing problems.

In order to represent CL roles (e.g., prerequisites), Isotani et al. [3] present a model, which uses ontology and is based on collaborative learning theories, to provide computational support for instructional design of CL scenarios and group formation. Despite the important contributions of Inaba and Mizoguchi [4] and Isotani et al. [3, 34] for group formation and instructional design of CL scenarios, *personality traits,* which are important elements that influence learning and collaboration, were not considered in their model [9].

Thus, to leverage previous achievements, the next section is dedicated to describe the process to establish the relationship between *personality traits* and *CL roles*. They give rise to a new kind of CL roles, which are referred in this paper as "Affective Collaborative Learning role" (ACL role). To formalize this relationship, Section 3.3

proposes an ontological structure to represent the ACL roles based on the established relationship of Section 3.2.

3.2 Relationship between Personality Traits and Collaborative Learning Roles

According to Sherman et al. [23], a human behavior is strongly related to how an individual handles the situation being experienced, where the individual personality traits influence the way in which this behavior is expressed. For instance, in a social situation a person who has extraversion personality trait seeks out social stimulation during his presentation, while an introverted person does not need such a social stimulus [24, 25]. Thus, in this section, our interest is to identify the personality traits that influence students' behaviors in different situations of CL scenarios. This task is done by establishing a process[2] that defines the relationship between the students' personality traits and the CL roles. The process is composed by four steps: (i) determine personality traits characteristics; (ii) identify which personality traits characteristics may affect negatively students' behavior in educational collaborative settings; (iii) define new collaborative learning roles given the personality traits; and (iv) establish learning strategies to ensure students' educational benefits.

Regarding the first step, *determine the personality traits characteristics*, Table 2 shows an example for the extraversion and introversion personality traits. The characteristics shown in Table 2 come from the psychological questionnaire EPQ-J (Eysenck Personality Questionnaire - Junior) [24, 25]. According to EPQ-J manual, an individual is considered "introverted" when his/her extraversion result in the test is *low* or *very low*, and a person is considered "extroverted" when his/her extraversion result in the test is *high* or *very high*. According to Table 2, each personality trait has its own characteristics that can be expressed by an individual in a CL scenario.

Table 2. Characteristics of the Introverted and Extroverted personality traits. Source: [24, 25].

Personality Traits	Characteristics
Introverted	Unsociable; reflexive; moody; anxious; rigid; pessimistic; reserved; quiet; passive; careful; peaceful; controlled; reliable; even-tempered; calm.
Extroverted	Impulsive; sensible; restless, aggressive; easygoing; optimistic; active; sociable; talkative; receptive; lively; unconcerned; leader.

The second step in our process (to define the relationship between personality traits and CL roles) is to *identify personality traits' characteristics that can negatively influence students' behavior*. For example, *unsociable* characteristic (introverted, Table 2) may be a threat for Anchored Instructor behavior of "*advising* to diagnose problems and give some advice to other learners" (Table 1). An introverted student who expresses unsociable behavior in a CL scenario may be close to interact with others students (avoiding to diagnose problems and give advice) if the learning

[2] Due to page restrictions, we show the application of our approach only to the *extraversion* and *introversion* personality traits. However, this process can be applied for any personality traits defined by personality theories, and any CL roles defined by Inaba and Mizoguchi [4].

environment, for example, only provides synchronous communication. According to Pavalache-Ilie and Cocorada [26], introverted persons feel more comfortable in asynchronous communication when compared to face to face communication (synchronous communication), because they prefer work at their own place and have more time for reflection. In this sense, Davidson et al. [30] present some strategies to optimize learning for introverted using asynchronous communication such as discussion forums and email exchanges.

Another possible threat for a CL scenario is the *impulsive* characteristic (extroverted, Table 2). This characteristic can negatively influence the Problem Holder behavior of "*presenting* to explain something in his/her mind to other learners". According to Bidjerano and Dai [27], extroverts may express difficulty in solving problems that require reflection. In general, they are incapable of deep reflection because they have a tendency to reach cognitive decisions prematurely.

This second step must be repeated to other personality trait characteristics or to their combinations. For example, let's suppose the *passive* and *reflexive* characteristics (inherent from introverted personality trait, see Table 2) are not considered a threat to students' behavior in group work when analyzed separately[3]. However, if the combination *passive + reflexive* is pointed out as a threat, it must be considered in the second step of our process. Thus, the number of characteristics or their combinations will depend on scientific findings that confirm this information.

Table 3 shows part of the results of this work by following this second step in which unsociable and impulsive characteristics (inherent from introverted and extroverted personality traits, respectively) may be considered threats for CL scenarios, based on the Anchored Instruction learning theory [21].

The third step of the process is the *definition of the "ACL roles" as a specialization of the "CL roles"* defined by Inaba and Mizoguchi [4]. For each personality trait and its combination with a CL role, we define an ACL role in which personality traits become necessary and desired condition to attribute this new role for a student. Table 3 shows four ACL roles that were defined for *introversion* and *extraversion* personality traits in CL scenarios, based on the Anchored Instruction learning theory [21]. These new roles are specializations of the *Anchored Instructor* and *Problem Holder* CL roles named as: *Introverted Anchored Instructor*, *Extroverted Anchored Instructor*, *Introverted Problem Holde*r, and *Extroverted Problem Holder*. We also include "Personality traits characteristics that may be threats" (column 3, Table 3) in CSCL scenarios design and "Behavior problem" (column 4) that can occur when the unsociable or impulsive characteristics are expressed in students' behavior. For example, when a student performs the new role *Introverted Anchored Instructor* (column 1), the *unsociable* characteristic (column 3) may cause the behavior "difficulty to guide/advise others" (column 4).

Finally, the fourth step in our process is the *definition of strategies to ensure educational benefits* when students' behavior problems related to their personality traits arise. In this sense, to avoid problems with *unsociable* characteristic (column 3, Table 3), it is suggested to "create conditions to promote asynchronous interaction" (column 6). As previously discussed, introverted people can feel more comfortable in

[3] It is worthwhile mentioning that this affirmation needs the support of scientific studies from Psychology, Pedagogy, or Education.

asynchronous communication using, for example, discussion forums or email exchanges [26, 30]. Thus, this strategy can be adopted for the student who performs the *Introverted Anchored Instructor* and *Introverted Problem Holder* roles, as shown in Table 3. To ensure educational benefits when extroverted students express *impulsive* behavior (column 6, Table 3), it is recommended the use of strategies as Brainstorming and Thinking Aloud [31] and or techniques to encourage the reflection, as a pause of 5-10 seconds to analyze a solution [30]. Therefore, for students who perform *Extroverted Anchored Instructor* and *Extroverted Problem Holder* roles, we define the strategy to "create situations that promote verbalization and encourage reflection", as shown in Table 3.

Table 3. ACL Roles for a CL scenario based on the Anchored Instruction learning theory [21].

ACL Roles	Prerequisites	Personality trait characteristic that may be threats	Behavior (problem)	Expected Benefits of Learning	How to ensure the educational benefits?
Introverted anchored instructor	*Having the knowledge. *Knowing how to diagnose others. - Not having experience in diagnosing others. *Having low or very-low introversion (introverted-oriented)	Unsociable	*Advising* to diagnose problems and give some advice to other. (Difficulty to guide/advise others)	Acquisition of content specific knowledge (tunning). Development of cognitive skill (associative stage).	Create conditions that promote asynchronous interaction.
Extroverted anchored instructor	* Having the knowledge. * Knowing how to diagnose others. - Not having experience in diagnosing others. *Having high or very-high extroversion (extroverted-oriented).	Impulsive	*Advising* to diagnose problems and give some advice to other. (Superficiality to diagnose problems and to give advice)		Create situations that promote verbalization and encouragement of reflection.
Introverted problem holder	* Having a problem. - Having the knowledge. *Having low or very-low introversion (introverted-oriented).	Unsociable	*Presenting* to explain something in his/her mind to other learners. (Difficulty to explain something).	Acquisition of content specific knowledge (*tunning*).	Create conditions that promote asynchronous interaction.
Extroverted problem holder	* Having a problem - Having the	Impulsive	*Presenting* to explain something in		Create situations that promote

	knowledge *Having low or very-low extroversion (introverted-oriented).		his/her mind to other learners. (Superficiality to explain something)		verbalization and encouragement of reflection.

In the next section we present the proposal of the ontological structures to represent ACL roles and its relationship with strategies to allow the expected educational benefits in different CL scenarios.

3.3 Ontological structure to represent the CL Roles improved by Personality Traits and its relationship with CL Scenarios

In this section, we extend the ontological structure proposed by Isotani et al. [3] with the purpose of representing ACL roles. Fig. 1 (a) shows the new ontological structure, which includes the personality traits as necessary and desired conditions, as indicated by the dashed lines.

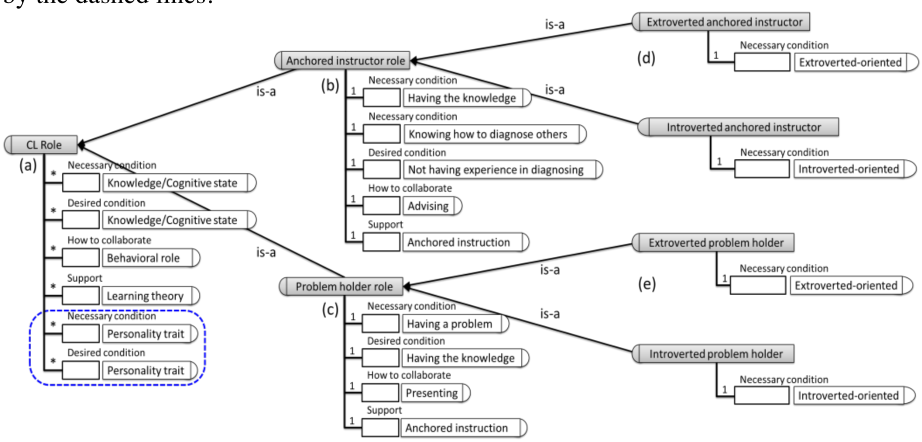

Fig. 1. (a) Ontological structure to represent the necessary and desired conditions to the ACL roles, and (d-e) examples of the ACL roles for CL scenarios based on the Anchored Instruction learning theory [21].

Based on the relationship between personality traits and CL roles detailed in Section 3.2 and using the structures proposed by Isotani et al. [3], we represent specializations of different roles for CL scenarios based on the Anchored Instruction learning theory [21]. For instance, Fig. 1 (d) shows the definition of "Extroverted anchored instructor" and "Introverted anchored instructor" roles, which are specializations of the "Anchored instructor" role, shown in Fig. 1 (b). As specialization of the "Problem holder" role (Fig. 1 (c)), we define "Extroverted problem holder" and "Introverted problem holder" roles, which are shown in Fig. 1 (e). Based on these examples, to perform the "Extroverted anchored instructor" and "Extroverted problem holder" roles, the student personality trait must be extroverted (*extroverted-oriented*). To perform "Introverted anchored instructor" and "Introverted problem holder" roles, the student personality trait must be introverted (*introverted-oriented*).

Using ontological structures that represent ACL roles, we can build new ontological structures to represent CL scenarios in which we define strategies to deal with personality traits characteristics which may negatively influence students' behavior. Fig. 2 shows the definition of two CL scenarios based on the "Extroverted/Introverted anchored instructor" and "Introverted/Extroverted problem holder" roles.

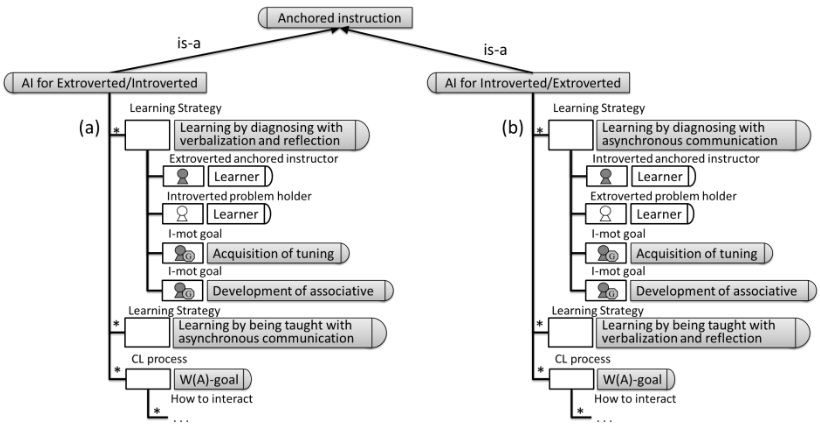

Fig. 2. Ontological structures to represent CL scenarios, based on the Anchored Instruction (AI) learning theory [21], that deal with possible threats (unsociable and impulsive) inherent to introverted and extroverted individuals.

The first structure "AI for Extroverted/Introverted" (Fig. 2 (a)) represents a CL scenario based on the Anchored Instruction learning theory [21] in which the student who performs "Extroverted anchored instructor" role will adopt the learning strategy "Learning by diagnosing with verbalization and reflection" to deal with the lack of reflection. In this scenario, "Learning by being taught with asynchronous communication" is the learning strategy that will be adopted by the students who perform "Introverted problem holder" role to deal with unsociable behavior. The second structure "AI for Introverted/Extroverted" (Fig. 2 (b)) defines the learning strategy "Learning by being taught with asynchronous communication" to be adopted by students who perform the "Introverted anchored instructor" role, and students who perform the "Extroverted problem holder" role will adopt the learning strategy "Learning by being taught with verbalization and reflection".

On both CL scenarios, the learning strategies "Learning by diagnosing with verbalization and reflection" and "Learning by diagnosing with asynchronous communication" are specializations of the learning strategy "Learning by diagnosing". Likewise "Learning by being taught with verbalization and reflection" and "Learning by being taught with asynchronous communication" are specializations of the learning strategy “Learning by being taught” for the CL scenarios based on the Anchored Instruction learning theory [21]. Based on learning strategies defined for students in a CL scenario, the ontological structure W(A)-goal (shown in Fig. 2) represents the CL process that will be employed to deal with the potential problems that can arise when personality traits characteristics, as unsociable or impulsive, may negatively influence students’ behavior.

4 Case Study

To evaluate our proposed model, we conducted a case study[4] to investigate whether the unsociable and impulsive characteristics, inherent from introversion and extroversion personality traits respectively, may negatively affect students’ performance when they play an ACL role, as defined in Table 3. Specifically, this work verifies students’ behavior when they perform these roles during a collaborative session defined in the ontological structures, as shown in the Fig. 2. The collaborative session has been performed in a Pre-Scientific Initiation program (Pre-SI[5]) at University of São Paulo, Brazil. This program aims to encourage students from two local high schools to exchange ideas and solve logic challenges using computer programs. Considering the favorable context to develop the research, we defined four hypotheses to be accepted or rejected at the end of this case study.

- Hypothesis 1: The *unsociable* characteristic, inherent to *introverted* individuals, is a threat that affects students’ performance when they perform the *Introverted Anchored Instructor* role in a collaborative session.
- Hypothesis 2. The *impulsive* characteristic, inherent to *extroverted* individuals, is a threat that affects students’ performance when they perform the *Extroverted Anchored Instructor* role in a collaborative session.
- Hypothesis 3. The *unsociable* characteristic, inherent to *introverted* individuals, is a threat that affects students’ performance when they perform the *Introverted Problem Holder* role in a collaborative session.
- Hypothesis 4. The *impulsive* characteristic, inherent to *extroverted* individuals, is a threat that affects students’ performance when they perform the *Extroverted Problem Holder* role in a collaborative session.

[4] A case study is a qualitative method that deeply observes a specific situation, context, person, or an event [33].

[5] The Pre-Scientific Initiation program (Pre-SI) is an initiative of our University to support the development of projects in STEM, Biological and Human Sciences areas. It aims to stimulate the interest in Science of students from public schools, through interaction with procedures and methodologies of scientific research.

4.1 Method

The case study was performed with Pre-SI students during December/2015. To conduct this research we had two collaborative learning activities of two hours each. The subject was the introductory concepts of C[6] programming language.

Participants. We conducted this case study with 10 students aged between 13-16, where five learners are female and five are male. Regarding schooling, seven students attend Secondary Technical School in Data Processing; two students attend the last year of Middle school and one student attends High school. Regarding students' knowledge of programming concepts, all students from Secondary Technical School (seven students) had some knowledge about programming language, while the other three students (Middle school and High school) have no knowledge of programming.

Study Design. This case study was divided in three stages: A) Pre-test, B) Collaborative Session, and C) Post-test. In the *Stage A* students answered three individual tests: knowledge test (pre-test), skill test, and psychological questionnaire. In the *Stage B* students received some orientation about the collaborative session and then they were grouped in pairs to solve the activities. Finally, in the *Stage C*, the students answered another knowledge test (post-test) to verify whether they had acquired new knowledge. The tests applied in Stage A and C were conducted using paper and pencil, and the activities of Stage B were performed in a computer lab of our University.

Stage A. In the first meeting, the students were instructed to answer three individual tests: a psychological questionnaire, a skill test, and a knowledge test (pre-test).

The psychological questionnaire EPQ-J (Eysenck Personality Questionnaire – Junior) [24] was designed to identify children and teenagers' personality traits (aged between 10-16). It contains 60 specific questions that aim to verify their behavior in daily situations. The EQP-J questionnaire used in this study is a validated Brazilian Portuguese language adaptation of Eysenck and Eysenck [25]. The time limit to answer the 60 questions was 20 minutes.

The knowledge test (pre-test) is composed of three tasks aiming to evaluate students' knowledge about the introductory concepts of C programming language: variable statement, assignment, reading, writing, and if-else decision command. The time limit to answer the exercises was 45 min, approximately, 15 min for each item.

The skill test, named "The astronaut choice[7]", aimed to identify students' ability to solve problems and work in groups (e.g., communication skills, management ability, ability to diagnose problems, among others). These abilities are necessary for students who perform the Anchored Instructor or Problem Holder roles [21]. We used a

[6] C is a structured programming language commonly used in technical courses in Computer Science (e.g., Data Processing) to teach basic programming concepts.

[7] *The astronaut choice* is an adaption of an Astronaut Nasa widely used in group dynamics. More information about this skill test is available at https://goo.gl/El41L7.

version of the Astronaut Choice translated to Brazilian Portuguese[8]; the time limit to answer it was 20 minutes.

Stage B. In the second meeting, before starting the collaborative session, we presented the guidelines of the case study for the students. Additionally, we conducted a pilot session to introduce the interaction strategies proposed by the Anchored Instruction learning theory [21]. Furthermore, we elaborated some help cards (in paper) to support students performing the Anchored Instructor and Problem Holder roles. Fig. 3 shows an example of a card to support students when they perform "Introverted problem holder" or "Extroverted problem holder" roles.

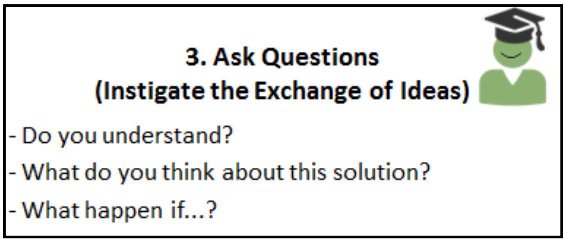

Fig. 3. Example of a card to support students when they perform the "Introverted anchored instructor" or "Extroverted anchored instructor" roles**.**

After that, students were arranged in pairs based on the grouping strategy defined by the Anchored Instruction learning theory [21] and the role to be performed by the learners in the collaborative session. The results of the tests of the *Stage A* (knowledge, skill and personality trait) were used to define the role each student should perform.

During the collaborative session, the groups used a desktop computer to solve two tasks regarding introductory concepts of C programming language: variable statements, assignment, reading, and writing. This test did not have problems about if-else command because in the knowledge test (*Stage A*) mostly of the students showed no mastery of this topic. The time limit to solve the tasks was 1h20, approximately 40 min for each problem.

Regarding the tasks, the first one presented a problem-situation for which students had to implement a solution using concepts of C programming language. The second problem presented a piece of code in C, in which students should identify and correct implementation errors.

In order to collect data about students' interaction during the collaborative session, three researchers used an observation protocol to guide the registry of the interaction strategies adopted by students. Two researchers observed two groups and the third researcher observed only one group. Each group interacted freely using the cards (e.g., Fig. 3) to support their interaction and without any intervention of the observers.

[8] The Brazilian Portuguese version of the Astronaut Choice is available at http://www.dinamicasdegrupos.com.br/dinamica-a-escolha-de-um-astronauta/.

Stage C. The last stage was an individual knowledge test (post-test). This test consisted of two tasks about introductory concepts of the C programming language (variable statements, assignment, reading and writing) aiming to verify students' achievement during the collaborative session. The time limit to solve the exercises was 30 minutes, approximately 15 minutes for each problem.

Results. All data collected in the *Stages A* and *C* (knowledge tests, psychological questionnaire, and skill test) and *Stage B* (observation protocol) are summarized in Table 4.

Table 4. Summary of case study results.

Student ID	ACL role	Achievement	Closeness	Social Interaction		Group Performance
				Socialization	Knowledge building	
S1a	IAI	High	Medium	Low	Medium	Medium
S1b	EPH	High	High	High	High	
S2a	EAI	Low	High	High	Medium	Medium
S2b	IPH	Medium	High	Low	Medium	
S3a	IAI	High	High	High	High	Medium
S3b	IPH	Low	Low	Low	Low	
S4a	IAI	Low	Null	Medium	Low	Low
S4b	IPH	Low	Low	Low	Low	
S5a	IAI	Medium	High	High	High	High
S5b	EPH	High	High	High	High	

The first column of Table 4, named "Student ID", represents the individual identification of participants in this case study. For the groups identification we use numbers from 1 to 5 for each pair. For instance, Group 1 (S1a and S1b), Group 2 (S2a and S2b), and so on. The second column, named "ACL role", represents the role performed by each student in the collaborative session, where IAI is the acronym for "Introverted Anchored Instructor"; EAI for "Extroverted Anchored Instructor"; IPH for "Introverted Problem Holder"; and EPH for "Extroverted Problem Holder".

This work takes into account the following factors to analyse the groups' performance: "Achievement" (column 3, Table 4), "Closeness" (column 4), social interaction related to "Socialization" (column 5) and social interaction to "Knowledge building" (column 6).

The "Achievement" factor (column 3, Table 4) represents the *knowledge acquired* (about the introductory concepts of C programming language of students) and the *effort* to achieve a higher score (based on pre and post-tests). We computed this factor using the following formula[9]:

$$Achievement = ((Knowledge\ Acquired + Effort)/2)/0.75 \qquad (1)$$

Where:

Knowledge Acquired =

((preT^2*(postT – preT)+(post^2)*(postT-pretT))/((minS^2)*maxS+(maxS^2)*maxS)

and

Effort = (preT^2 + postT^2)/(maxS^2+maxS^2)

preT = *score of the pre-test*
postT = score of the post-test
minS = minimum score in both pre and post-tests
maxS = maximum score in both pre and post-tests

Based on this formula, we classified students' achievement as follows: *Null*: 0 (zero); *Low*: value between [0 - 0.33); *Medium*: value between [0.33 - 0.66); and *High*: [0.66 - 1].

The "Closeness" factor (column 4, Table 4) refers to a person's tendency to get closer or further away of specific situations that occur during group interaction (e.g., conflicts, arguing, discussion, among others). In this work, we verified this tendency based on the following attitudes expressed by students: *concentrated*, *reflective*, *disperse*, *open*, *receptive* and *communicative*. For this factor, we used the following scale: *Null*: for students with disperse attitude; *Low*: for students who showed one attitude different of being disperse (e.g., communicative or receptive); *Medium*: for students who showed two attitudes different of being disperse (e.g., open and receptive or reflexive and concentrated); *High*: for students who showed three or more attitudes different of disperse (e.g., concentrated, open and receptive, or reflection, open and concentrated).

The "Socialization" factor (column 5, Table 4) refers to the act of joining a group and developing a cooperative spirit. We defined the scale based on the following attitudes expressed by the students: *communicative*, *receptive* and *open*. Thus, *Null*: means none of these attitudes were observed during students' interaction; *Low*: means one attitude; *Medium*: means two attitudes; and *High*: means all three attitudes.

The "Knowledge building" factor (column 6, Table 4) is related to the intensity of the social interactions that promote the exchange of ideas among peers through

[9] The cardinal 0.75 is used to normalize the formula, whereas *(Knowledge Acquired + Effort)/2* has the maximum value of 0.75.

dialogues, discussions, arguments, among others. In this sense, we develop a scale based on the following students' actions: ask questions, answer questions, encourage reflection and organization of ideas (only to students who perform Anchored Instructor role), demonstrate comprehension (only to students who perform Problem Holder role). Thus the scale adopted was: *Null*: means none of these actions were observed during students' interaction; *Low*: means one action; *Medium*: means two actions; *High*: means more than two actions.

In order to create a numeric scale to each factor (Achievement, Closeness, Socialization, and Knowledge building), we established the score 0, 5, 10 and 15 to the elements *Null*, *Low*, *Medium* and *High*, respectively. Thus, final group performance (column 7, Table 4) is given by the sum of the factors applied to the Anchored instructor and Problem holder roles. The scale adopted for this case is: *Null Performance*: 0-30; *Low Performance*: 31-60; *Medium Performance*: 61-100 and *High Performance*[10]: 101-120. For example, we calculated Group 1 (S1a x S1b) performance as follows:

***S1a** (Achievement+ Closeness + Socialization + Knowledge Building) + **S1b** (Achievemtn + Closeness + Socialization + Knowledge Building) = Final Group Performance.*

***S1a** (15+ 10 +5 +10) + **S1b** (15 +15 +15 +15) = 100*

The score 100 rates Group 1 as a *Medium Performance* group.

Analysis and Discussion. Next, we analyze and discuss the case study results based on four hypotheses presented in the beginning of Section 4.

Hypothesis 1. The *unsociable* characteristic, inherent to *introverted* individuals, is a threat that affects students' performance when they perform the *Introverted Anchored Instructor* role in a collaborative session.

Students who performed the Introvert Anchored Instructor (IAI) role belong to the following groups: Group 1 (Medium Performance), Group 3 (Medium Performance), Group 4 (Low Performance), and Group 5 (High Performance).

Regarding Group 1, results showed the student S1a (IAI) presented difficulty in social interaction, as shown in Table 4 by factors: "Closeness" *medium*, "Socialization" *low*, and "Knowledge building" *medium*. Although the student S1a (IAI) has been receptive to the colleague's questions, he/she was not communicative during the entire collaborative session. For this reason, we can conclude the unsociable characteristic negatively affected the S1a (IAI) student's performance when he/she performed the Anchored Instructor role.

With regards to Group 4, the student S4a (IAI) was dispersed during the entire collaborative session. Therefore, the "Closeness" factor was null. Moreover, he/she was impatient and authoritarian in some moments to present and explain the concepts to S4b (IPH) student. Consequently, "Knowledge Building" was *low* and "Socialization" was *medium*, as shown by Table 4. Considering the *low* performance

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[10] We defined a group as *high performance* when their members achieve *medium* or *high* scores, where the minimum amount of high scores must be *five*.

of Group 4 and the reluctance of student S4a (IAI) to work collaboratively, we see the unsociable characteristic as a threat to students who play the IAI role.

Differently from previous groups, S3a (IAI) and S5a (IA) students were receptive and communicative during the entire collaborative session. Table 4 confirms this analysis with the value *high* to the factors: “Closeness”, “Socialization” and “Knowledge Building”. As these students (S3a and S5a) were open to interaction, we cannot use these groups to verify if unsociable characteristic is negative to IAI role.

Concerning the analysis about S1a (IAI) and S4a (IAI) students’ performance in the groups, the collected data showed evidences that the unsociable characteristic may negatively influence student’s behavior when he/she performs IAI role. Consequently, we accept the hypothesis 1. This result suggests that unsociable characteristic should be considered in designing of CSCL scenarios and personalized systems to form high performance groups.

Hypothesis 2. The *impulsive* characteristic, inherent to *extroverted* individuals, is a threat that affects students’ performance when they perform the *Extroverted Anchored Instructor* role in a collaborative session.

As presented in Table 4, the only group in which a student performed the Extroverted Anchored Instructor (EAI) role was Group 2 (Medium Performance). Although student S2a (EAI) was communicative and open to interaction during the entire collaborative session (“Closeness” *high*, “Socialization” *high*), he/she needed to use the cards (e.g., Fig. 3) to organize his/her ideas and verify which strategy to use in order to help S2b (IPH) student (“Knowledge building” *medium*). For example, provide examples, explain some concept, ask questions, among others. We believed the help cards, in this context, worked as a strategy to incite the S2a (EAI) student reflection, which contributes to him/her achieve the educational benefits. Accordingly, the hypothesis 2 cannot be accepted or rejected.

Hypothesis 3. The *unsociable* characteristic, inherent to *introverted* individuals, is a threat that affects students’ performance when they perform the *Introverted Problem Holder* role in a collaborative session.

Students who performed the Introverted Problem Holder (IPH) role are in the following groups: Group 2 (Medium Performance), Group 3 (Medium performance) and Group 4 (Low performance).

Regarding Group 2, the student S2b (IPH) had *high* “Achievement” and he/she was receptive to the S2a (EAI) questions during the entire collaborative session (“Closeness” *high*). However, we observed that the S2b (IPH) student showed difficulty in expressing his/her opinion, which affected the social interaction with S2a (EAI). This difficulty is confirmed by factors: “Socialization” *low* and “Knowledge building” *medium*. S3b (IPH) and S4b (IPH) students, belonging to Groups 3 and 4 respectively, also had social interaction difficulty (“Socialization” *low* and “Knowledge building” *low*) and avoided arguing and discussing during the collaborative session (“Closeness” *low*).

Considering that S2b (IPH), S3b (IPH) and S4b (IPH) were not open to interaction (unsociable) and that this behavior affected (threat) their performance in group work, we accept the hypothesis 3.

Hypothesis 4. The *impulsive* characteristic, inherent to *extroverted* individuals, is a threat that affects students' performance when they perform the *Extroverted Problem Holder* role in a collaborative session.

Students who performed the Extroverted Problem Holder (EPH) role belonged to the following groups: Group 1 (Medium performance) and Group 5 (High performance). We observed that the S1b (EPH) and S5b (EPH) students participated actively of the collaborative session, presenting their doubts, answering questions, giving their opinion, among others. The factors "Closeness" *high*, "Socialization" *high* and "Knowledge building" *high*, in Table 4, demonstrate this aspect. Additionally, these students (S1b and S5b) reflected and analyzed the proposed solutions to the tasks. As in both groups (1 and 5) the students had a good performance and have not demonstrated an "impulsive" behavior, we cannot accept or reject hypothesis 4.

5 Conclusions

This study extended existing researches on group formation in CSCL in several ways. Firstly, we presented a process to model new collaborative learning roles (ACL roles) to improve the formation of high performance groups. This model was built in four steps: (1) determine personality trait characteristics; (2) identify which personality traits characteristics may negatively influence students' behavior; (3) define the "ACL role"; and (4) establish strategies to ensure students' educational benefits. It is worthwhile mentioning that this process can be applied for any personality traits defined by personality theories and any CL roles presented by Inaba and Mizoguchi [4]. Secondly, we presented an ontological structure to represent "ACL roles" and its relationship with strategies that ensure the expected educational benefits in different CL scenarios (Fig. 1). Based on this structure, we built a new ontological structure to represent CL scenarios (Fig. 2) to deal with possible threats (unsociable and impulsive) inherent to introverted and extroverted individuals, respectively. In order to evaluate this approach, we performed a case study that grouped ten Pre-Scientific Initiation program (Pre-SI) students from University of São Paulo in pairs based on *introverted* and *extroverted* personality traits and *Anchored Instructor* learning theory.

Our case study showed evidences that *unsociable* characteristic, inherent to *introverted* individuals, may negatively affect students' performance when they play the *Introverted Anchored Instructor* (Hypothesis 1) and *Introverted Problem Holder* (Hypothesis 3) roles. On the other hand, the hypotheses that investigate whether the *impulsive* characteristic, inherent to *extroverted* individual, is a threat to students who play *Extroverted Anchored Instructor* (Hypothesis 2) *and Extroverted Problem Holder* (Hypothesis 4) cannot be accepted or rejected by this case study.

This work contributes to the design of CSCL scenarios and personalized systems, whereas our approach presented a model to personalize the formation of groups using personality traits and CL roles. In addition, we believe that this model is a step forward to understand the impact of personality traits in group formation and students' learning in CSCL context. As future work, we plan to expand our analysis running controlled experiments with larger groups of participants, which will allow us to apply inferential statistics to accept or reject our hypotheses. We also intend to apply the proposed process to other personality traits (e.g., neuroticism, psychoticism [24, 25]), as well as other collaborative learning theories (e.g., Peer Tutoring [36], Cognitive Apprenticeship [22]). Concerning the ontological model, we are going to work in specialization and formalization of the existing strategies to deal with possible threats related to personality traits.

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