The effect of individual preparation on knowledge acquisition and student attitudes towards collaborative inquiry activities in International Baccalaureate schools

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Abstract

This research investigated the effect of activating prior knowledge by individual preparation on knowledge acquisition, retention and students' attitudes towards future collaborative tasks. Fifty-eight secondary students (16-18 years old) in three International Baccalaureate (IB) schools worked with a PhET simulation on gravity and orbits. Students in dyads were randomly assigned in two groups: an experimental group where prior knowledge was activated individually by reading summary, and a control group with no treatment before the collaborative task. Data was gathered from a pretest on prior knowledge about gravity, a post-test and a delayed test on concepts of gravity and circular motion, and a cooperation/collaboration questionnaire. No significant differences between conditions were found on knowledge gains. Individual preparation in International Baccalaureate schools had no significant effect on learning gains in a collaborative inquiry environment. Additionally, it had no significant effect on students' attitudes toward collaboration.

Keywords

Collaborative inquiry learning, experiment design, prior knowledge, individual preparation, attitude, IB schools

1.0 Introduction

Nowadays, educational scientists aspire to prepare future citizens for an increasingly demanding work environment where collaboration across disciplines and consciously doing research to tackle problems, are of utmost importance (Matuk & Lin, 2018; Latour & Woolgar, 2013; van Laar, van Deursen, van Dijk & de Haan, 2017). The latter reflects on how collaboration is embraced as an approach to learning within schools (Oliveri, Lawless, & Molloy, 2017; Akkerman et al., 2007). Collaboration and inquiry labelled as “twenty-first-century skills” are expected to be demonstrated repeatedly across one's professional lifespan (Somekh, 2007; Kreijns, Kirschner, Vermeulen, 2013). Not surprisingly, educators are focusing on using teaching approaches that help students to develop these skills (Welsch, Agostino, & Eastwood, 2014; Gokhale, 1995; Thomas, Ssendiaddiwa, Mroz, Lockyer, Kosarzova, & Hanna, 2018).

More specifically, twenty-first-century skills have been incorporated into the curriculum of international schools (IB) worldwide. IB schools accept students from different countries, with different mother tongue, different sociocultural values and backgrounds. Throughout the framework of the IB programs, an emphasis is given on creating successful collaborative environments where students are able to work together, to develop their interpersonal skills and intercultural understanding (IBO, 2013). Students are expected to develop non-cognitive competencies such as working as a team, interacting with peers and actively showing independence in the learning process (https://www.ibo.org). “To be able to collaborate effectively” is one of the 10 attributes of the IB learner profile. The IB learner profile is the pillar of the International Baccalaureate (IB) program, as part of standards that students should grasp by the end of their secondary school education (Harney, Hogan, & Quinn, 2017; Haldimann & Hollington, 2004). It is closely related to the heart of the International Baccalaureate Organisation (IBO) that refers not only to a “knowledgeable”, “thinker” student who acquires in-depth knowledge and develops new concepts through interactions, but also to a “communicator” and an “open-minded” student who collaborates willingly with others and evaluates different opinions (Thomas et al., 2018; Barratt Hacking, Blackmore, Bullock, Bunnell, Donnelly, & Martin, 2017; Bullock, 2011). According to the educational belief that collaborative inquiry learning (CIL) could be a strong learning environment, International Baccalaureate (IB) schools encourage collaboration and inquiry by designing learning tasks that cultivate science process skills to learn science through group assignments, discussion, and fruitful interactions (Ryan, Tocci, Ensminger, Rismiati, & Moughania, 2018).

Although collaborative inquiry learning is a key element in the International Baccalaureate (IB) curriculum, implementation in a daily practice could be a challenge due to students ’different nationality and educational background (Dickson, Perry, & Ledger, 2018**;** Weinberger & Shonfeld, 2018; OECD, 2017). Moreover, students at IB schools quite often, even in the middle of an academic year, may need to transfer to a different school and country. The importance of these changes has been recognized as a factor that may affect students ’emotional well-being, relatedness and connectedness which subsequently may have an impact on students’ performance if their sense of belonging is at low-level (Durlak, Weissberg, Dymnicki, Taylor, & Schellinger, 2011).

Students learn in schools in the company of their peers. These relationships and how students feel may facilitate or hinder engagement, motivation, commitment to their learning (Laal & Ghodsi, 2012). Culturally diverse students in a new school setting, lack of connection, emotional stress, feeling socially unsafe or less competent in English may be components of a foundation which impede adjustment (Eisenberg, 2006; Gunder, Caldarella, Korth, & Young, 2012). Cooker, Bailey, Stevenson, and Joseph (2016) claim in their study that a students' feeling of connectedness and belonging may affect their academic performance due to the time needed for their adjustment to the new school environment which may cause depression, social withdrawal, anxiety and lack of motivation. These emotions may not promote interpersonal skills and it is a challenge for teachers to help students establishing, maintaining positive relationships by taking into consideration the social complexities due to students’ different academic values and experiences.

It would be beneficial for educators to know if there are instructional practices which enhance implementation of CIL in the International Baccalaureate (IB) context and counteract students’ difficulty of acclimatization. Therefore, the purpose of this study is to explore whether individual preparation as a method supports CIL in terms of knowledge acquisition and retention as well as a positive predictor of students' attitudes towards future collaborative tasks. This study will explore whether students demonstrate and develop collaborative inquiry skills. (Lamsa, Hamalainen, Koskinen, & Viiri, 2018; Schmidt, 2015; Biggs, 2003; Levallet & Chan, 2016). Furthermore, this study will explore whether students demonstrate a more positive attitude towards future collaborative tasks.

1.1 Collaborative learning.

Collaboration is an educational approach that focuses on individuals learning in a small group (two to five students) through a joint effort for a common goal of a group to share and solve a problem (Dillenbourg, 1999; Paulus, 2005). The benefits of collaborative learning (CL) are well documented with regards to learning gains. Research findings have consistently shown that students collaborating in small groups achieve higher learning outcomes than individual students and the effect size in comparison to individual learning varies from 0.58 to 0.70 (Johnson, Johnson, & Stanne, 2000; Johnson et al., 2014; Johnson & Johnson, 1999; Janssen, Kirschner, Erkens, Kirschner, & Paas, 2010). While the superiority of CL is by and large accepted, simply asking students to work together does not, by definition, guarantee improvement on student achievement (Barron, 2003).

Many things can occur during group processes in a collaborative setting while students participate in group work. Lack of self-esteem, lack of prior knowledge to work from on the topic given and lack of confidence on expressing or advocating their positions could make the learning process tedious or overwhelming (Laal, 2013). Interactions among peers play an important role by building on each other's different point of views while they share their ideas (Le, Janssen, & Wubbels, 2018). In a collaborative situation, students' deeper learning could be promoted by discussing with their peers, presenting and defending their arguments while they are working together and sharing tools to complete a task or solve a problem (Laal & Laal, 2012). This form of learning is considered as an advantageous over individual learning and it correlates with improvement of student performance when it is combined with inquiry (Saab, van Joolingen, & van Hout-Wolters, 2012).

Externalization is important in the inquiry context. If students do not succeed in the process of exchanging ideas and externalize them more explicitly, meaningful learning might be not successful (Eysink & de Jong, 2012). Externalization allows students to learn from each other's argumentation and reasoning. More specifically, when students are able to explain, verbalize and investigate concepts in science in a collaborative learning environment, they have the opportunity to detect weak points on their knowledge (Van Boxtel et al., 2000). Based on various studies we can conclude that collaborative inquiry learning promotes learning in STEM context, by allowing students to engage in science inquiry (their own and their peers) via discussions (Li, Hong, Chai, Tsai, & Lin, 2018; Olsen, Rummel, & Aleven, 2017; Yeh, Huang, Chan, & Chang, 2016; Wang, 2016).

1.2 Inquiry learning.

Collaboration and inquiry have been identified as 21st-century learning skills for New Millennium Learners (P21, 2012; Voogt, Erstad, Dede, & Mishra, 2013; OECD, 2017). CL experiences are seen as an effective approach to foster inquiry skills while at the same time emphasize each phase of the inquiry cycle such as observation, exploration, conclusion and discussion (Manlove, Lazonder, & de Jong, 2006).

According to constructivism, inquiry is considered as an approach that leads to active and meaningful learning through the integration of background knowledge with new information aiming to learning gains (van Riesen, Gijlers, Anjewierden, & de Jong, 2018; Tsovaltzi, Judele, Puhl, & Weinberger, 2014). It is widely accepted that inquiry learning can result in deep understanding in science curricula (Lazonder & Harmsen, 2016; Jiang & McComas, 2015). It is significantly supported by computer-based learning which enables students to follow methods of a professional scientist and helps them thinking of experimental research. Students are able to assimilate information, stimulated by curiosity and intentional research (Bell, Urhahne, Schanze & Ploetzner, 2010; Suarez, Ternier, Prinsen, & Specht, 2016). Pedaste et al., (2015) argue that inquiry learning engages students as critical thinkers, familiarizes them with scientific practices. The same authors claim that students discover knowledge through inquiry phases following a scientific process.

Simulation based computer supported inquiry learning environment provides students the opportunity to explore and observe a variety of scientific phenomena, by following the inquiry learning cycle (generate questions, formulate and validate hypotheses, analyze data, draw justifiable conclusions and discuss them), in a safe environment (Pedaste et al., 2015). Through these inquiry learning processes students build knowledge to make sense of the world (Magee & Flessner, 2012).

Next to acquiring STEM related domain knowledge inquiry learning is considered an excellent way to teach students how to expand their knowledge base using inquiry skills (Lazonder, Wilhelm, & van Liebourg, 2009). In addition, inquiry learning stimulates discussions among students and enables them to make discoveries in their attempt to answer questions, their own or their peers.

1.3 Collaborative inquiry learning.

By merging collaborative and inquiry learning, students make decisions together, exchange ideas on which steps to follow. In doing so, they imitate how scientists share accountability to address problems and develop skills that may facilitate team and task regulation, negotiation (Saab, van Joolingen, & van Hout-Wolters, 2012). In collaborative inquiry students need to agree and consider the contributions of others in order to construct knowledge together (Gijlers & de Jong, 2013).

To highlight the pedagogical value of CIL, Chen, Wang, Kirschner & Tsai (2018), in their meta-analysis which included findings of 425 empirical studies, found that collaboration had significant positive effects on knowledge acquisition and student perception. Research findings have shown that CIL bolsters delayed learning gains and acts as an impetus for the students to improve their understanding of science through discourse (Hmelo-Silver, Jeong, Faulkner, & Hartley, 2017; Menekse & Chi, 2018). Understanding in science entails the ability to identify scientific issues and understand concepts (Bush et al., 2017).

Collaborative tasks could be beneficial. Prior research across domain areas has shown that through activities in a face-to-face setting, students are able to re-evaluate their existing knowledge, often in an unpredictable way, by reasoning about their decisions and presenting their sophisticated strategies (Jensen & Lawson, 2011; Matuk & Linn, 2018). Group discussions may facilitate the detection of misconceptions, triggered by students' effort to make their thoughts understandable to their peers (Tracey, Joiner, Kacin, & Burmeister, 2018; Chan, Lam, & Leung, 2012). Moreover, through the communication and discussions in CIL, students actually use the subject related terminology in other words they learn to "talk science" (Lemke, 1990).

Van Boxtel (2000) pinpoints that identifying relations between different variables, in terms of increases or decreases, may promote a deeper understanding of the specific domain. Through externalization of their ideas, investigation of variables, interrelations or underlying laws involved, students reach an agreement on how to execute the given task which in turns enable them to construct knowledge together (Widiyatmoko, 2018; Rau, Aleven, Rummel, 2017; Gijlers & de Jong, 2005). To go through this phase and the problem-solving process in an efficient way, prior knowledge is essential. If students have different level of prior knowledge, they might encounter difficulties in reaching a mutual understanding and in finding a common method in order to complete an assignment (Weinberger & Shonfeld, 2018).

After examining a large meta-analysis Hattie and Donoghue (2016) found that activating prior knowledge is a prerequisite that supports student's inquiry. Adequate prior knowledge in IL increases the likelihood of making inferences, and it enables students to reach conclusions based on scientific explanations rather than misconceptions (Fan, Geelan &

Gillies, 2018; Sangra, Gonzalez-Sanmamed & Guitert, 2015). When existing knowledge on the given topic is not activated, students are minimally prepared prior to the inquiry task resulting in less active involvement and dialogical processes. Non-activated knowledge hinders them from engaging in scientific investigations. Using textual cues such as a summary may serve as a stimulus that familiarizes students with the upcoming new material by bringing them relevant stored information that aids the comprehension and the assimilation of the new topic (Fisher & Frey, 2009). Having a base information to work from, students are able to formulate explanations and to address scientifically oriented questions (Moon, Stanford, Cole, & Towns, 2017) which increases their engagement to the learning process in combinations with the dynamics of interactions (Stover & Holland, 2018; Sangin, Molinari, Nüssli, & Dillenbourg, 2011).

1.4 Individual preparation and knowledge gains.

Empirical findings have shown that providing some information on the domain prior to the inquiry task as individual preparation method could compensate for a low level of prior knowledge (Phillipson, Ku & Phillipson, 2014). It may also support students to overcome learning barriers by offering the chance to have even a general knowledge of the domain (Wetzels, Kester, & Van Merrienboer, 2011; Lazonder et al., 2009). They might be able to reflect on their own knowledge of the specific domain and improve their comprehension and their meta-comprehension accuracy (Arnold, Kremer, & Mayer, 2014). Prior knowledge is the foundation on which students learn and understand and it allows students to discover facts and details more efficiently (Schmidt, De Volder, De Grave, Moust, & Patel, 1989; Harrison, 2015) by developing brain schemata connecting facts to concepts and by identifying patterns and principles (Donham, 2010; Shapiro, 2004). When students detect and repair through peer discussions what they have learned well or not, they are more conscious of their own understanding and the interplay between prior knowledge. This ultimately facilitates new information (Saido, Siraj, Nordin, & Al-Amedy, 2017; Ozuru, Dempsey, & McNamara, 2009). Thus, the learning of new material by investigating links underlying a topic might be reinforced (Henderson, 2007; Hailikari, Katajavuori, & Lindblom-Ylanne, 2008).

This is corroborated by the study of Van Boxtel et al., (2000). They suggest that individual preparation might provide the opportunity to clarify any misconceptions and any gaps in students' knowledge by making them aware of deficits in their reasoning or strategies (Lamsa et al., 2018; Hausmann, Chi, & Roy, 2004). Misconceptions as a troublesome situation have been examined and documented mostly in science and physics (about velocity, motions, and forces) (Erkens & Bodemer, 2019; Liu, Liu, & Lin, 2018). If misconceptions remain unsolved, due to the fact that scientific phenomena consist of interconnected elements, students may perceive science as a difficult subject (Mulder, Lazonder, & de Jong, 2015). Allowing time for individual preparation before a collaborative inquiry activity provides students with time to examine what they know, what is missing, and how they can correct misunderstandings in their attempt to integrate the new material (Jensen & Lawson, 2011; Hailikari et al., 2008; Lam & Kapur, 2017; Ertl & Mandl, 2008; Loibl & Rummel, 2014a).

1.5 Individual preparation and attitudes towards collaboration.

Despite the beneficial effects of learning at the group level, students' characteristics such as their experiences and feelings in previous collaborative tasks, may affect how peers work in a group and how they perceive collaboration as adding value to their learning (Gomez, Wu, & Passerini, 2010). Often educators' efforts reveal students' reluctance to engage in collaborative tasks. It appears that students could be incredulous to their peers' knowledge as a source of information (Matuk & Linn, 2018; Erkens & Bodemer, 2019). Difficulties arise during collaboration with regards to the intertwined elements of a joint effort, individual contribution and interpersonal communication skills (Lai 2011; Scager, Boonstra, Peeters, Vulperhorst, & Wiegant, 2016).

If they experienced low confidence in previous collaborative assignments, they tend to become less participative, less engaged and the learning process at the group level is unlikely to be effective (Lee & Tsai, 2011). Their belief in their competence and ability to take on tasks may influence the way they perceive collaboration (Zeidan & Jayosi, 2015; Bang & Baker, 2013).

Additionally, when they encounter difficulties in recalling something already learned and they might experience deactivating emotions (Noroozi, Biemans, Busstra, Mulder, & Chizari, 2012). Individual preparation may facilitate students in their attempt to construct arguments by offering time to prepare their solutions, to clarify their own understanding by increasing their awareness related to what is expected from them and by developing assertiveness and a more positive attitude (Weinberger, Stegmann, & Fischer, 2010; Clark, Sampson, Weinberger, & Erkens, 2007; Schwarz & Linchevski, 2007). Mukai (2017) argues, that the opposite could hinder student's expected involvement, activeness, and participation in an on-going discussion. Students with low confidence with regards to their expected level of knowledge on a topic might feel unsafe and they might be reluctant to share their arguments with their peers resulting in low-quality, narrow discussions and unequal turn-taking within the group (Brooks & Jeong, 2006).

According to Lam and Kapur, (2017), when students activate prior knowledge, readiness for learning may be increased and they may be more motivated to get involved in the task given with peers and jointly elaborate ideas while participating with confidence and clarity in knowledge building activities (Tracey et al., 2018; Fakomogbon & Bolaji, 2017; Bereider & Scardamalia, 2014; Ionas, Cernusca, & Collier, 2012). How students argue on a task given or even how competent they feel using appropriate language and terminology of science in a group setting, could have an impact on students' attitudes (Peklaj & Levpušček, 2006; Philiex, Prins & Kirschner, 2010). The feeling of "getting stuck" could hinder their attempt to be more involved and it may affect their willingness to participate in future group works (Lee & Tsai, 2011). Individual preparation prior to a task could decrease the time needed for its completion, helps students to negotiate effectively reflecting more accurate understanding and a knowledge basis shared by group members (Tsovaltzi, Judele, Puhl, & Weinberger, 2015; Hogan, Nastasi, & Pressley, 2000; Amigues, 1998).

Despite the consensus derived from research that a collaborative learning environment is an effective instructional approach, the question that mainly concerns researchers now is not whether collaboration is advantageous, but how students' learning gains can be optimized in a collaborative context, how a successful collaboration can be sustained (Janssen et al., 2010; Wiley, Goldenberg, Jarosz, Wiedmann, & Rummel, 2013) and to what extent communication and students' interactions can be fostered (Kollar, Wecker, Langer, & Fischer, 2011; Rummel & Spada, 2005; Dillenbourg and Jermann, 2007). According to Stahl (2017), every occurrence of CL is unique and involves complex interactions. Therefore, additional research is needed to investigate the degree to which instructional techniques such as individual preparation used by educators can increase the effectiveness of collaborative inquiry learning.

2.0 Experimental Design & Research Questions

The current study aims to explore the effect of individual preparation as a tool to activate prior knowledge in CIL. It differs from previous studies by investigating the impact of individual preparation specifically in an International Baccalaureate (IB) school setting. Two conditions differed with respect to individual preparation that had been used to activate prior knowledge. In the experimental condition, a paper-based summary was given to students and in the control condition, no text was given. Both conditions worked on the same simulation and on the same task in dyads.

Secondly, since research findings have shown that activating prior knowledge is a key component in conceptual learning (Linnenbrink-Garcia, Pugh, Koskey, & Stewart, 2012; Rittle-Johnson, Star, & Durkin, 2009), the present study uses a posttest and a delayed test that measure the learning benefits after the collaborative task.

Thirdly, the current study uses a cooperation/collaboration questionnaire that measures students' willingness or reluctance in participating in future collaborative tasks and explores whether individual preparation positively affects their perception about collaboration. In the two conditions, a pretest, posttest, delayed test, and a cooperation/collaboration questionnaire were administered. In the experimental condition, a summary was given with the basic concepts of gravity at the beginning of the activity. Participants were randomly assigned to the conditions. The present study focused on the following research questions:

Research Question 1:
To what extent does individual preparation as a strategy to activate prior knowledge have an impact on conceptual learning in a collaborative inquiry task in terms of knowledge acquisition and retention?

Activation of prior knowledge could facilitate students ’inquiry skills and how confidently they verbalize that knowledge in order to make inferences and understand new concepts (Hodges, 2018; Lam, Io-Low & Li, 2018; Kobbe et al., 2007). In the individual preparation phase, students become aware of their misunderstandings, notice inconsistencies in their thinking, and are able to clarify their reasoning before sharing their ideas with peers (Linn & Eylon, 2011; O'Donnell, Hmelo-Silver, & Erkens, 2005).

The conceptual learning was measured by a posttest and a delayed test. It was expected that the experimental condition with the summary given as individual preparation would demonstrate higher scores and greater improvement of conceptual understanding on the immediate posttest.

Research Question 2:
Is there a correlation between individual preparation and student attitudes towards future collaboration?

Individual preparation in science courses may have an impact on social skills by allowing students to participate in discussions during collaborative tasks with confidence and clarity (Wright & Lee, 2014). It will give them the time needed to confirm their beliefs or to correct their misconceptions and inconsistent reasoning. This may encourage a more positive attitude towards collaboration decreasing the risk of or reformulating prior negative experiences during a collaborative activity (Johnson, Johnson, Roseth, & Shin, 2014). This paper argues that the provision of a summary or texts for individual preparation may influence the attitude of students with regards to future collaborative tasks. It was expected that the experimental condition would demonstrate a more positive attitude towards future collaborative tasks.

3.0 Method

3.1 Experimental study design.

The main focus of the current study is the effect of individual preparation as a tool of activating prior knowledge on students' learning gains about circular motion and gravity in physics. Furthermore, this paper explored whether individual preparation may have an impact on students' attitude and perceptions towards future collaborative inquiry activity. Two conditions were compared, each of which involved fourth grade international high school students who worked in pairs in a simulation-based inquiry learning environment.

Participants had to learn about circular motion and gravity in a collaborative inquiry learning environment. The two conditions differed with respect to the extra intervention provided: an individual preparation activity. Fifteen dyads were randomly assigned to undergo an extra treatment by receiving a summary for individual preparation (the experimental group) and 14 dyads received no treatment (the control group).

3.2 Participants.

A total of 58 DP year 1 secondary high school students, approximately 17 years of age, participated in the current study. All students had not been taught recently gravity and circular motion. Participants were randomly assigned to the conditions. The students participated in the experiment during their regular science class. Consent letters were provided to ensure that their participation was not obligatory. Students worked in dyads by sharing a computer and a task. Students were not familiar with Gravity and Orbits, but they were acquainted with gravity as a concept from previous physics classes. The main learning task was to discover the underlying physics forces. During the task they had to describe the relationship between the planets and space station and predict how motion will change if gravity is stronger or weaker as it is presented in Figure 2.

3.3 Domain.

Physics as science involves the study of universal laws and relationships among physical phenomena. Concepts of circular motion is part of secondary school science curriculum. Circular motion is part of rotational dynamics, a significant topic in physics that acts as a gateway for the understanding of other topics in physics. It is among the phenomena that everyone experiences in daily life. It is important for students to understand practical applications. The learning environment in the current study concerned the physics domain of circular motion and more specifically on gravity and orbits. Studies, although limited in number on student’s concepts on gravity and mass have shown misconceptions. Having a force at a distance and its effects (such as gravitational force, gravitational acceleration) it is hard to grasp as concepts which render conceptual understanding of gravity and mass on earth and space difficult (Gönen, 2008; Kikas, 2003). Similar research findings have shown that students could encounter difficulties with regards to determine the speed at some points and the forces acting on an object in circular motion mostly in space (Mashood & Singh, 2012; Kokkonen, 2017; Close, Gomez, & Heron, 2013). Students could be confused about how to solve related problems such as orbital dynamics or to explain the orbital motion of the Moon and to understand the significance of the velocity for satellite motion (Erceg, Aviani, 2014; Duman, Sekercioglu, 2015; Pol, Harskamp, Suhre, & Goedhart, 2008). They may not be able to understand that circular motion could occur in diverse forms such as gravity or in space with no earth atmosphere (Heard & Aravind, 2010; Seattha, Yuenyong, & Art-in, 2015).

3.4 Learning environment and materials.

In the current study, students in two conditions worked in simulation-based inquiry learning environment. A well-designed simulation may help students to observe what is often not visible to the eye and to understand scientific concepts (Fan, 2015; Wieman, Adams & Perkins, 2008). The simulation-based inquiry activity used in this research was the PhET simulation on gravity and orbits. The chosen type of simulation (Physics Education Technology Project) can be free downloaded and more information on the PhET program and examples can be found on the website ((http://phet.colorado.edu). The PhET project is designed to help students in an interactive way connecting real life phenomena and science (Perkins et al., 2006). The basic feature of PhET simulations is supporting scientific cause-effect relations in inquiry learning.

3.5 Simulation computer-based environment.

The operation of the learning environment was identical for both conditions. Students were able to turn on and off the gravity button, to move the sun, earth, moon and space station (Figure 1, top right). They could manipulate the variables such as star mass or planet mass by selecting different values and observe the effect on gravity. By choosing one of the boxes on the right side of the screen, the participants could observe how gravity force or velocity could change. By clicking the "undo" button on the right top side of the screen, they could reset and rerun the simulation.

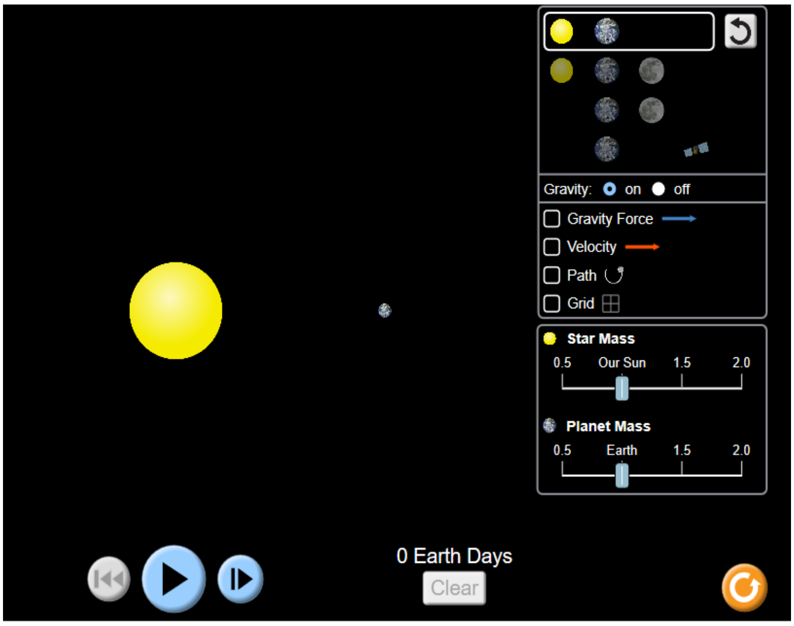


Figure.1 Screenshot of the simulation-based activity

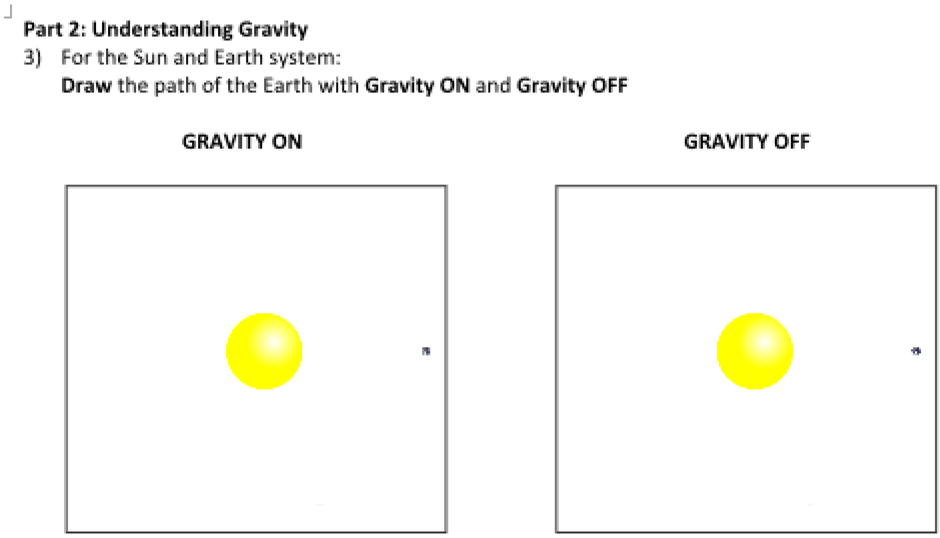


Figure.2 Task in pairs

3.6 Summary given as individual preparation.

Besides the simulation-based activity, a summary was provided as a treatment in the experimental condition only. The choice of giving a summary (Figure 7) was based on the construction- integration model of Kintsch (1988) who stated that a specific description of concept even in a text could trigger prior knowledge and activate concepts from long term memory which help students incorporate new concepts and obtain gains in subject domain knowledge. Additionally, multiple representations of concepts such as diagrams, pictures or formulas could play a positive role in learning physics (Maries & Singh, 2017).

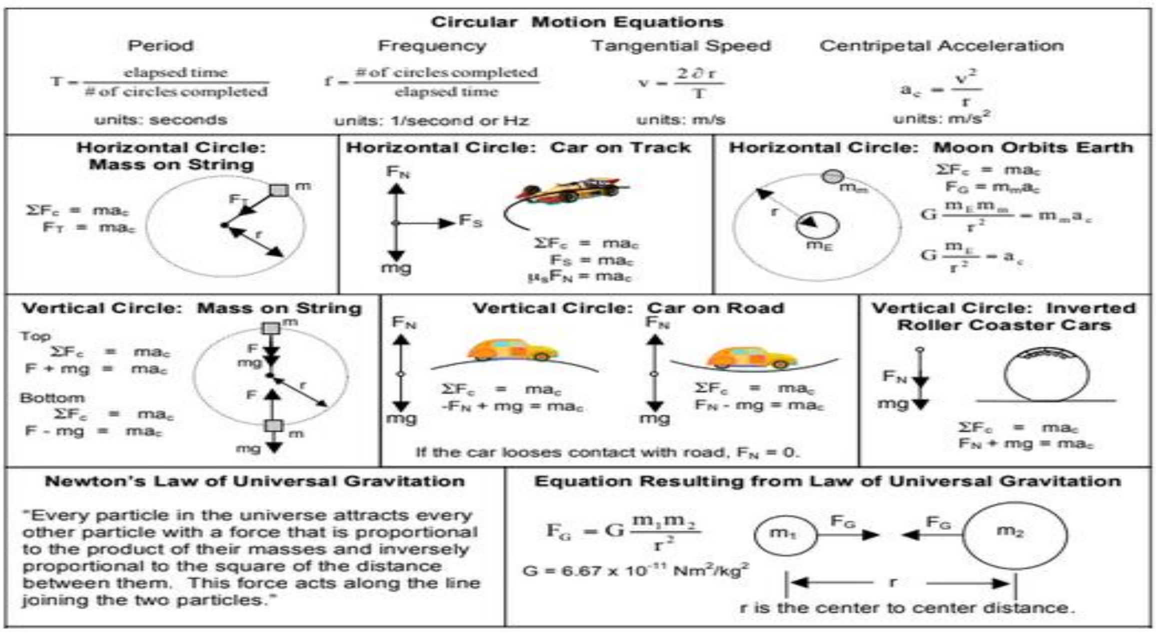


Figure.7 Summary sheet for individual preparation.

3.7 Experimental condition.

In the experimental condition, the intervention was carried out. It was investigated whether activating prior knowledge could increase knowledge acquisition and retention by providing them a summary with the basic concepts and diagrams related to gravity force and motion. It was also investigated if individual preparation could influence students' attitude towards future collaborative activities.

3.8 Measurement instruments.

Domain knowledge test.

Three different versions of a knowledge test on circular motion and gravity were administered. The first version was a pretest (see Appendix C) which was administered to ascertain that participants had similar level of prior knowledge about circular motion before the simulation-based activity. It consisted of 5 multiple choice questions which allowed students to gain 5 points (Figure 3).

The second version was an immediate posttest (see Appendix D) which measured knowledge acquisition about circular motion and orbits. It was a parallel version of the pretest with only one more item added at the end aiming at measuring conceptual knowledge. It contained a total of 6 multiple choice questions which allowed students to gain 6 points (Figure 4).

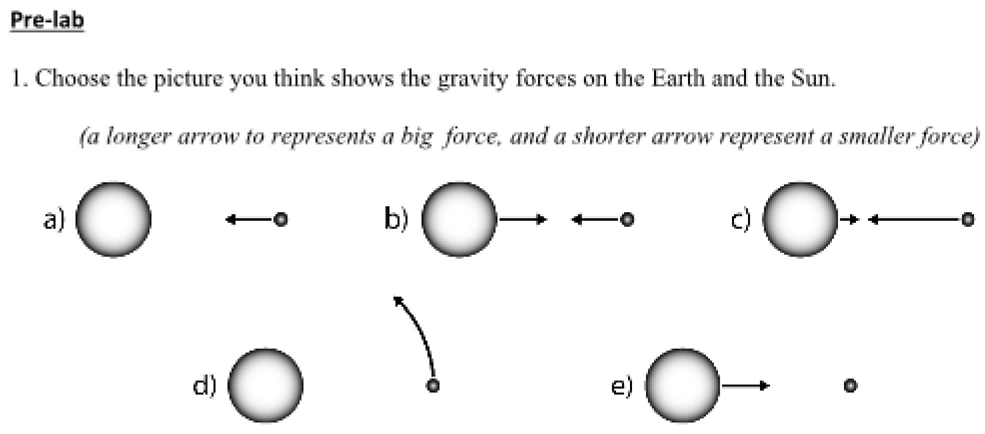


*Figure.*3 Pretest

6. Choose the picture of how the Earth would move if you "turned off" the gravity forces.

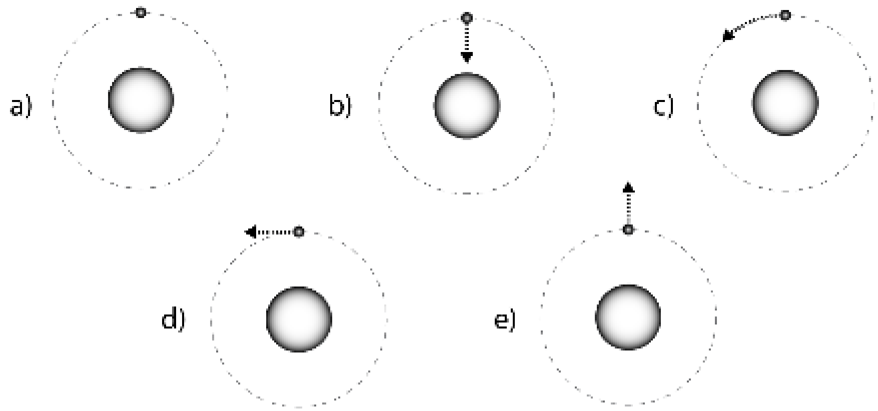


Figure.4 Posttest

The third version was a delayed test (see Appendix E) aiming at measuring retention of conceptual knowledge. The delayed contained different types of items test. Five of these items were multiple choice questions and four of these items were True/False questions which allowed to students obtain in total nine points for the entire test. An example of the delayed test is:

1. The force of gravity between two planets depends on their

   A. masses and distance apart.

   B. planetary atmospheres.

   C. rotational motions.

   D. all of the above

Figure.5 Delayed test

Cooperation/Collaboration Questionnaire

To measure how students perceived the collaborative aspects of this task, a questionnaire was administered in both conditions. The questionnaire was administered in class after the posttest to ensure a high response rate. The participants submitted the questionnaire once they completed it. The objective of the questionnaire was to measure whether students' attitude towards collaboration could be related to their individual preparation prior to collaboration. The questionnaire contained in total 17 statements (see Appendix F for a full list of the statements) in a 3 Likert scale starting (disagree, more or less agree and totally agree). Example of the statements included is given below (Figure 6).

	Disagree	More or less agree	Totally Agree
Everyone listened to each other.	☐	☐	☐

*Figure.*6 Cooperation/Collaboration Questionnaire

3.9 Procedure.

Figure 8 shows the flow of the experiment. The experiment was carried out in total three schools, one International Baccalaureate school in the Netherlands and two International Baccalaureate schools in Greece. Before conducting the experiment, the permission of principals in all the International schools was been asked after sending an email in order to explain the purpose of this study. Consent letters were provided to students for their participation. An appointment with the physics teacher was scheduled to explain the procedure during the experiment and to ensure smooth progress during the session. The study was conducted in their regular classroom, because this could offer better insights into students natural learning environment and increase the ecological validity of this study. The preset maximum of the session was 45 minutes and no extra time was needed.

Before the intervention, all participants took a knowledge pretest. Students were given five minutes to complete the pretest. Two days later, students were assigned to their conditions. First students were assigned to conditions and within the conditions were randomly assigned in pairs.

The session started with a ten- minute introduction, where participants were informed about the nature and the aim of the study and informed about their rights. It was explained that during the experiment any support from the teacher was not allowed. After the introduction the dyads were invited to work on the inquiry learning task. The participants were shown instructions on how to access the simulation in PheT environment. Students in the experimental condition received the short summary (see Appendix B) for individual preparation in order to activate their prior knowledge. They studied the summary for five minutes (Figure 7). Once they were done reading the summary, they started exploring the topic on gravity and orbits in the simulation. No summary was given to the control group. Students in both conditions were allowed to work on the simulation for 25 minutes. They used a hand-out that provided some structure and guidance (see Appendix A). a digital timer was projected on the interactive whiteboard to provide the students with an idea of the time.

After completing the simulation-based activity the posttest (five minutes) and a Cooperation/collaboration questionnaire (five minutes) were administered. After four days a delayed test (10 minutes) was administered to measure the knowledge retention on circular motion and gravity. The delayed- test consisted from a total of 9 questions.

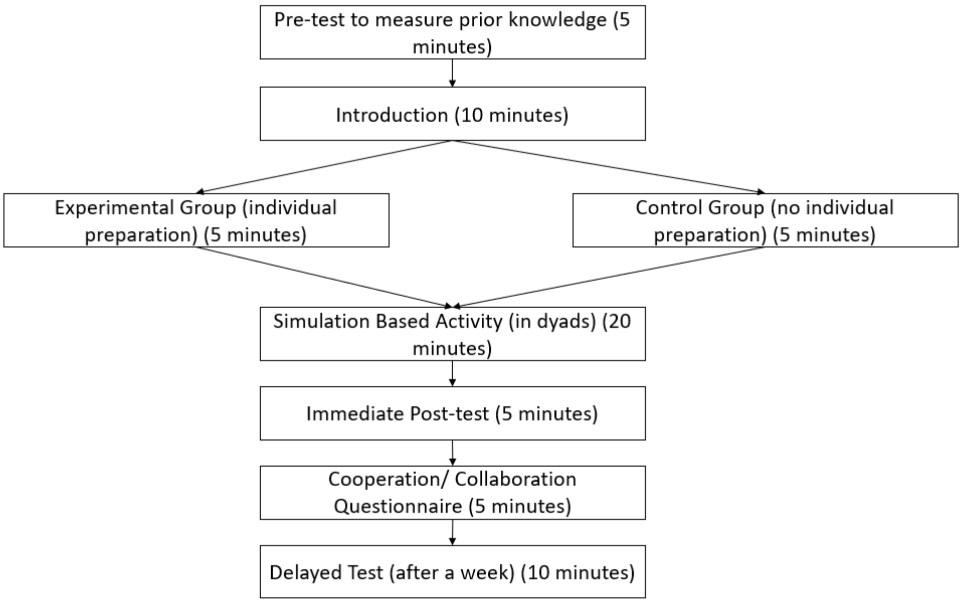


*Figure.*8 Flowchart of the experimental procedure

4.0 Data Analysis

Before conducting the analysis, it should be mentioned that due to privacy policy in IB schools, it was not allowed to have audio or video recordings. Due to this policy, only quantitative data were collected. A significance level of alpha .05 was used for all tests conducted as regards all possible comparisons. The statistic d of Cohen was used for evaluating the effect size during the mixed ANOVA (d=0.2 corresponding to small effect size, d=0.50 corresponding to medium effect size and d≥0.8 corresponding to large effect size).

4.1 Data analysis of collaborative learning variable.

The suitable statistical method for analyzing whether there is a statistical significant difference in the average values of Cooperative/collaborative learning Variable between the two educational groups (experimental and control) is the independent samples t-test, after checking whether the data are normally distributed, separately for experimental and control group (Rice, 2006). The index variable corresponding to the cooperative/collaborative learning follows the normal distribution (p>0.05) for both experimental and control group.

4.2 Construction of cooperative/collaborative learning variable.

The cooperative/collaborative learning index was constructed by the unweighted mean value of the 17 component variables after recoding the variables corresponding to negative questions. Answers were scored as follows: -1-> Disagree, 0->More or less agree and 1 -> Totally Agree.

5.0 Results

5.1 Pre-lab, post-lab & delayed exam performance.

Standard procedures were used for data analysis, including Levene's test of Equality and Greenhouse-Geisser tests to assess homogeneity of groups.The descriptive statistics (mean & standard deviation) are presented in table 1 for both groups (control & experimental) and for all three time points.

Table 1

Means and standard deviations for grades by educational intervention

	Pre-Lab		Post-Lab		Delayed		Total	
Intervention Group	M	SD	M	SD	M	SD	M	SD
Control (n=28)	0.56	0.24	0.84	0.19	0.65	0.17	0.68	0.2
Experimental (n=30)	0.61	0.22	0.91	0.12	0.73	0.19	0.75	0.18
Total (n=58)	0.59	0.23	0.88	0.16	0.69	0.18	0.72	0.19

The multivariate tests, i.e. Wilks' Lambda, to measure performance including pretest, posttest and delayed variables, showed that there is a statistically significant effect of time ($F_{2,55}$=75.875, p<0.01). In the contrary, there is not a statistically significant effect of interaction between conditions & time ($F_{2,55}$=0.121, p=0.886>0.05). The value (0.734) partial eta squared corresponds to large effect size. In the case that there is not a statistically significant interaction of individual preparation and knowledge gains, the main effects are provided from the Tests of Within-Subjects Effects. Specifically, the Greenhouse-Geisser test ($F_{1.7,94.7}$=48.555, p<0.01) shows that there is a statistically significant difference between at least 2 time points as regards the tests' mean values. In addition, the Greenhouse-Geisser test ($F_{1.7,94.7}$=0.169, p<0.01) shows that there is not a statistically significant interaction between time and intervention group, which is in accordance with the result of multivariate tests. Between-subjects effects test declares that the intervention group does not have a statistically significant effect in students' grades ($F_{1,56}$=3.330, p=0.073>0.05) and only the 5.6% of variance in the dependent variable can be explained by group/educational method. The two different educational groups have the same effect in points.

5.2 Questionnaire evaluation cooperative/collaborative learning.

After the comparison of the mean values of cooperative/collaborative learning variable between experimental and control group it appeared that the difference is not significant (t=0.454, p=0.652>0.05) (see Table 2). The experimental group achieved greater mean collaborative score vs control group but not statistically significant different.

Table 2

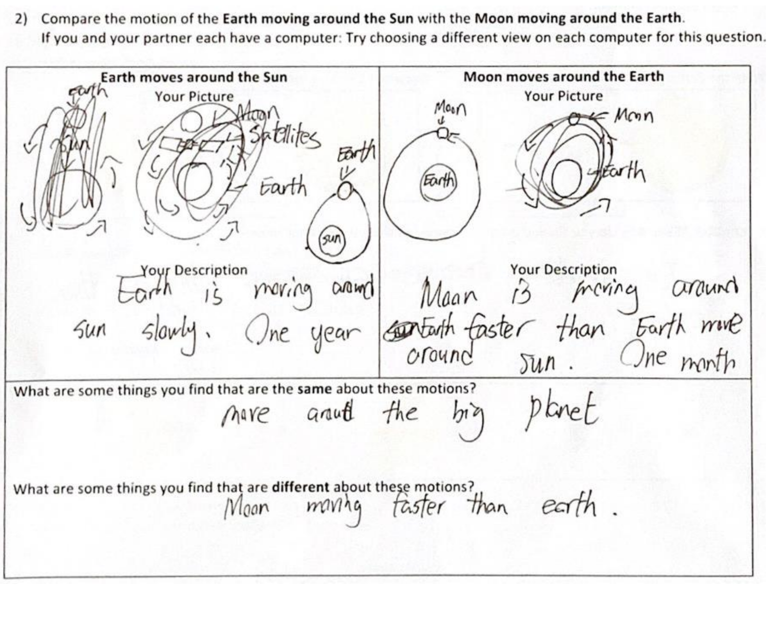
Means and standard deviations for cooperative/collaborative learning scores per intervention group

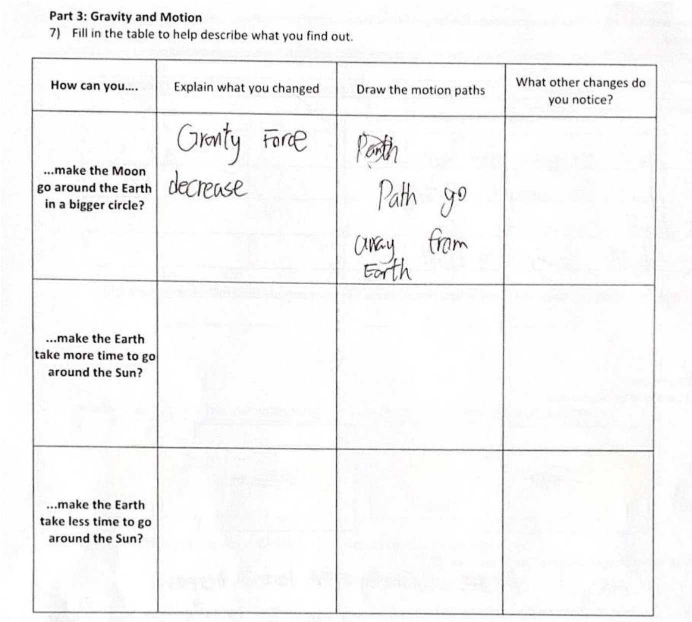
	Collaborative score		Test	
Intervention Group	M	SD	Levene's Test	t-test
Control (n=28)	0.458	0.310		
Experimental (n=29)	0.493	0.270	F=0.860, p_v=0.358>0.05	t=0.454, p_v=0.652>0.05
Total (n=57)	0.476	0.288		

5.3 Case analysis: a closer look at the experimental condition.

In this part, we focus on two dyads which have drawn the attention during data analysis, with regards to the collaborative inquiry task and to cooperation/collaboration questionnaire. In order to better understand the collaborative inquiry learning process in both groups we zoom into their work. The following report is subjoined as an added value of the results findings to show that the effect of the same treatment could vary on conceptual learning and students' perception about collaboration. In the first dyad of students (pair A), one student was Asian, one was Ukrainian and in the second one (pair B), one student was Asian, one was Greek.

In the first section of the activity, it was assumed that the participants would explore the simulation-based environment in order to observe Earth and Moon motion, to describe findings enriched with causal relations; to check differences or similarities; to manipulate variables and, most important to link the new concepts to activated prior knowledge and integrate it for meaningful learning. Comparing these 2 dyads in the quantitative analysis, there were detectable differences. The first dyad (Figure 9) did some drawings as it was expected, but their drawings were discernible. What is remarkable is that their explanations given were less elaborated in comparison with the dyad B. The pair B had better drawings by using arrows in order to show the motion and their explanations included even time values (Figure 10).



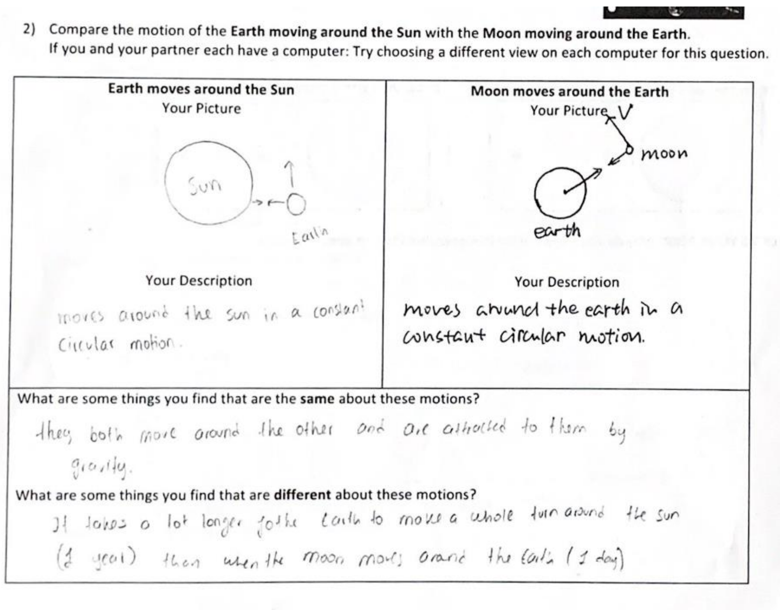


Part 3: Gravity and Motion

7) Fill in the table to help describe what you find out.

How can you....	Explain what you changed	Draw the motion paths	What other changes do you notice?
...make the Moon go around the Earth in a bigger circle?	Gravity Force decrease	~~Path~~ Path go away from Earth	
...make the Earth take more time to go around the Sun?			
...make the Earth take less time to go around the Sun?			

Figure 9. Answer-sheet of dyad A



2) Compare the motion of the **Earth moving around the Sun** with the **Moon moving around the Earth**.
If you and your partner each have a computer: Try choosing a different view on each computer for this question.

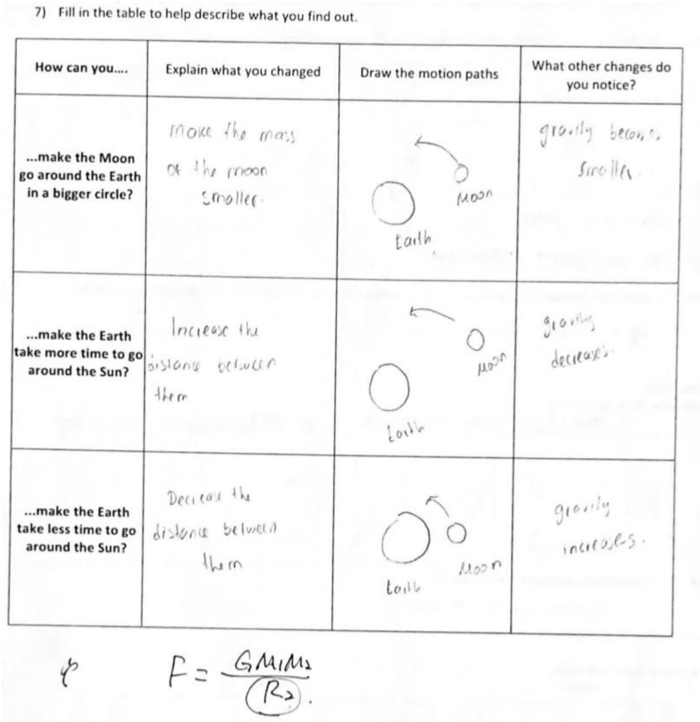
Earth moves around the Sun	**Moon moves around the Earth**
Your Picture	Your Picture V
Sun Earth	moon earth
Your Description	Your Description
moves around the sun in a constant Circular motion.	moves around the earth in a constant circular motion.

What are some things you find that are the **same** about these motions?

they both move around the other and are attracted to them by gravity.

What are some things you find that are **different** about these motions?

It takes a lot longer for the Earth to move a whole turn around the sun (1 year) than when the moon moves around the Earth (1 day)



7) Fill in the table to help describe what you find out.

How can you....	Explain what you changed	Draw the motion paths	What other changes do you notice?
...make the Moon go around the Earth in a bigger circle?	Make the mass of the moon smaller.	Moon Earth	gravity becomes smaller.
...make the Earth take more time to go around the Sun?	Increase the distance between them	Moon Earth	gravity decreases.
...make the Earth take less time to go around the Sun?	Decrease the distance between them	Moon Earth	gravity increases.

$F = \frac{GM_1M_2}{R_2}$.

Figure 10. Answer-sheet of dyad B

The first pair was relatively late entrance students in the IB program which requires some time of adjustment. Moreover, except the IB program and to what extent they were familiar with that, they were not English native speakers. Both of the students of the first pair took extra English lessons (called pre-IB courses). The second pair had graduated from MYP (Middle Years Program of IB curriculum). Both students were familiar to the IB program and they had better English level. The dyad A merely used words related to physics terminology for example decrease or increase which may demonstrate conceptual learning. Instead, they wrote small and very simple sentences where verbs are missing or using general scientific words such as “is big “. In other words, they mentioned some similarities or differences without elaborating on them. They asked their teacher twice during the activity whether it was allowed to use an online dictionary. It occurs that perhaps they encountered difficulties in using the appropriate words and that is also reflected on the last section of the assignment where most of the boxes are not fulfilled. Their attempt to attain the concept of circular motion, gravity and relevant variables was less efficient.

In contrast, dyad B was able to write more explicitly using words which reflected familiarity with physics terminology. They completed the last section of the answer sheet and they were able to find out what was the information needed in the simulation, to describe their findings by elaborating on them. These differences might at least in part be attributable to English as the language in which IB program is offered. After an informal meeting with the teachers we found out that both of the students in dyad A had lower level in English (less than 6 in IELTS) unlike the students in dyad B who had a higher level (IELTS 6.5). English level could be a problem and an explanation to what went wrong. Even though, for students in dyad A preparatory courses were provided to increase their English level, they were relatively new as students in the IB program.

In the Cooperation/Collaboration Questionnaire, it was assumed that it might be possible for students to develop a more positive attitude towards future collaborative tasks by receiving the treatment which might enable them with more confidence in the collaborative setting. The effectiveness of this treatment though, might be challenged by linguistic or cultural differences that students may have during collaborative inquiry tasks that an international school program entails in the curriculum. In the statements related to their perception of the collaboration as an added value in inquiry learning there was a difference on their beliefs. In the statements:

"By working in a group, I learned more than when I had to do the assignment alone", and "I have learned a lot from this assignment", dyad A disagreed (Figure 11), in contrast with dyad B who totally agreed (Figure 12).

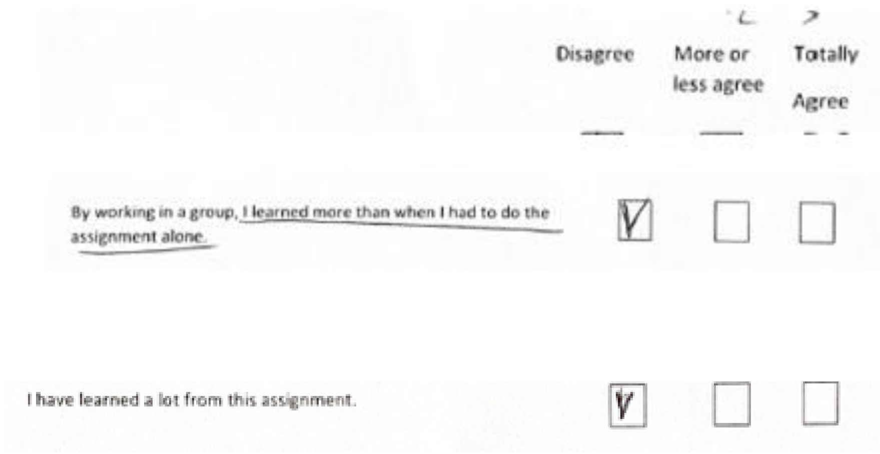


Figure 11. Statements of dyad A

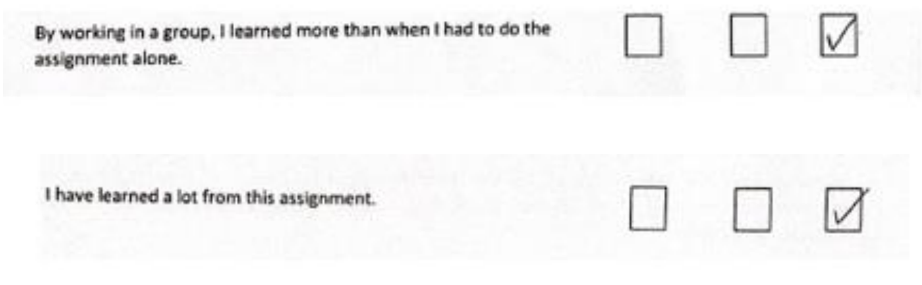


Figure 12. Statements of dyad B

Different answers were also found in the statements with regard to the perceived climate during the collaborative activity. In the statements:
"we looked each other in the eye while working together" and "we let each other speak without interrupting", pair A disagreed, in contrast with pair B which more or less agreed or totally agreed.

What becomes salient from this case analysis is that the timing of their entrance in the IB program and their English level could be positive or negative predictors of collaborative score. Collaboration depends on good communication. Different cultures could have different styles of communication and different understanding of what is good education. Research findings have shown that one fundamental process of a collaborative activity is a meaningful dialogue among students. This might be difficult when students whose English is not their native language, struggle to develop their competency in science literacy or they experience negative feelings such as shyness and face-saving (Adams, Jessup, Criswell, Weaver-High, & Rushton, 2015). As a result, the way the words are expressed may lead to miscommunication. Moreover, language is often related to cultural differences and learning at a group level could be a cultural shock for them. Thus, their resistance to CIL could be attributed to a teacher-centered and competition- oriented model of learning. Being familiar with an educational approach where basic components are obedience to the teacher and memorization in order to achieve high scores, could make the transition in later stage to the IB program more challenging (Hwang, 2013; Li & Cambell, 2008).

6.0 Conclusion and Discussion

This study investigated the impact of individual preparation as a tool to activate prior knowledge in physics, on learning outcomes and on students' perceptions of future collaborative activities. The underlying idea was that the learning outcomes and collaboration could be improved by an individual preparation strategy prior to a collaborative inquiry task. Activation of prior knowledge was further assumed to increase learning gains and to influence students' perceptions towards collaboration.

The first expectation was that the summary given as individual preparation tool could increase significantly learning outcomes in the domain of physics. There was no significant difference between the two conditions.

The lack of effect may, in part, be due to the educational setting where the experiment took place taking into consideration not only students' different citizenship status but also the fact that the majority of students have been in an IB school for a long period. According to the literature, one of the fundamental elements of IB curriculum in all three programs (Primary Years Program/PYP, Middle Years Program/MYP, and Diploma Program/DP) is inquiry and concept- based learning influenced by a constructivist approach. IB learner profile, the pillar of IB emphasizes on developing an inquirer and knowledgeable person (Daly, Brown, & McGowan, 2012). In MYP and PYP, a PBL approach with benchmark lessons is implemented in order to enable students with sufficient inquiry strategies. The latter means that IB students are familiar with similar activities and expectations such as analyzing and synthesizing information. In the conceptual understanding of science courses, by interdisciplinarity and integration of knowledge in different courses based on understanding that knowledge is contextual, IB curriculum enables students to be information seekers with matured inquiry skills (Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, 2015).

Since there were no differences in prior knowledge, the student's level of prior knowledge could be a moderating factor. Evidence from relevant studies arguing that high science prior knowledge could facilitate the integration of new knowledge into the existing by allowing students to identify more easily causal relations between old and new concepts in science (Tan, 2018). The IB program is oriented to understand how to learn and link prior knowledge with new information or to apply it to novel situations through interdisciplinary group projects (Marshman, 2011). In IB curriculum, sustained inquiry is promoted in daily teaching practices even in PYP (IBO 2014b, p.19). In PYP, learners explore, observe and re-explore concepts within and across subjects before the transition to the MYP and DP (Jamal, 2016; IBO, 2014). Looking at this structured way of IL implementation, it might be easier for IB students to obtain a higher level of prior knowledge.

It has to be acknowledged that due to the lack of significant positive effect in the delayed posttest, this study does not provide support for the hypothesis that individual preparation prior to a collaborative inquiry task may increase knowledge retention. Despite the fact that there are studies in favor of presenting basic ideas prior to inquiry (De Jong, & Van Joolingen,1998), so students could observe and identify variables more successfully, the summary given may have resulted in only short-term effects and no long-term effects were found. The small advantage of the experimental group was not long-lasting in the delayed test. This seems to be in line with research findings that new information is vulnerable and tend to be forgotten (Norman, 1968). It takes time for our brain to retain new information and make the leap into the long-term memory by creating a long-lasting neural network (Shultz, Cowles, & Ferraro, 2010). Gradually learning new concepts and repeatedly, seems to be the best way. One explanation for these results could be the time frame of the delayed test without any mention of the topic from their teacher before the delayed test. Students had not the opportunity to examine if they understood the new concepts. Along with findings from related studies, repetition and practice spaced out in time promote the retention of knowledge in the long-term memory (Mayer, 2004). There was no significant difference, albeit the highest scores obtained in the experimental group may be explained by the activation of prior knowledge relevant to the topic which might allow better knowledge integration and conceptual learning (Erkens & Bodemer, 2019). Taking that into account, reading a summary with the basic concepts might enable students to observe and identify variables based on simple memorization of basic laws in the specific domain (Wecker, Rachel, Heran-Dorr, Waltner, Wiesner, & Fischer, 2013).

The second expectation was that individual preparation prior to a task could have a positive impact on students' attitudes towards collaborative activities. This hypothesis was not confirmed by the results. Results have shown that even though the experimental condition achieved a greater collaborative score, the comparison yielded no significant difference between the 2 conditions.

This might be explained by the implementation of the IB program and curriculum. One of the fundamental concepts embedded in MYP is intercultural awareness, collaboration, and communication. Students are provided in all three IB programs opportunities to work with peers which familiarize them with group work which includes debates, role-play, group research and projects (Saxton & Hill, 2014; Harrison, 2015). Perhaps the majority of this specific sample was familiar with group assignments. That was confirmed after meeting the physics teachers. Most of the students were at the same school for 4 or 5 years. It is also possible that students' high level of prior knowledge in both conditions influenced the effect size. If students feel confident about what they know they are more likely to be positive towards collaborative activities. The aforementioned seems to be in line with previous studies that show concern about the extent to which individual feelings interweave with collaborative work (Barsade & Gibson, 2012). In contrast, when students feel uncertain, negative deactivating emotions may arise such as anxiety; therefore, it is more likely that collaboration is experienced in a negative way (Pietarinen, Vauras, Laakkonen, Kinnunen, & Volet, 2019; Zambrano, Kirschner, Sweller, & Kirschner, 2019). Another explanation could be the requirements for the level of English language in order to enter the program. It is important for students to be able to communicate almost fluently when they are non-native English speakers. In CIL students while they work towards an assignment, they could learn and benefit from this learning environment through exploration, discussion and scientific reasoning which by definition, at least to a certain extent, it presumes that students have some actives experiences and familiarity with inquiry skills but also that they can use scientific terminology. According to Magen-Nagar and Shonfeld (2018), an interpersonal event such as communication, discussion could influence the sense of competence and could increase the motivation to participate in collaborative activities. It cannot be neglected that when language is a barrier, communication and collaboration could be a challenge in terms of sharing, expressing ideas, and having a positive attitude during a group assignment (Ramlan, Abashah, Samah, Rashid, & Radzi, 2018). This is also reflected in how IB supports non-native speakers by providing extra courses in order to overcome their language gaps.

There are a few limitations to be pointed out. Firstly, the study was made in a real setting that increased the ecological validity, but the time pressure of the school schedule may have affected the overall activity and thus their results. If individual preparation phase was longer (and not only 5 minutes), students would have more time to reflect on what they know and more time to recall background knowledge related to the topic. If the experiment could last more than a session, the time provided for collaboration and peers discussion could be adequate to allow students formulating and evaluating explanations during the simulation. That could be possible by reset the simulation-based activity and change or explore the variables multiple times. Only one session was provided for the experiment procedure of 45 minutes. The experimental treatment was too short to cause a significant effect.

Due to the constraints the cooperation/collaboration questionnaire was administered one time, after the intervention. Perhaps it would have been better to administer this questionnaire before and after the intervention. In doing so, the researcher could investigate more accurately whether there was a change in students' attitudes towards collaborative activities. The relatively moderate sample size could be a limitation of this paper by reducing perhaps the power of statistical analysis. The majority of studies investigating collaborative inquiry learning take into account process data including the discourse produced by dyads. There is a possibility that the main effect of the study was attenuated by only performing quantitative analysis.

We suggest that in future studies investigating the effects of preparation on CIL log files and video data should be included. Furthermore, a multimethod approach is suggested including interviews of students in order to conduct a more comprehensive research. The impact of intercultural differences on collaborative tasks in a second language will be interesting to be explored. With discourse analysis, we could explore how cultural differences could affect collaboration, motivational states and cognitive engagement in IB schools.

The results seem to suggest that IB curriculum develops across the continuum students' inquiry and collaborative skills. We therefore think it would be interesting to compare IB schools with schools following the national curriculum over a longer period of time and to assess the development of inquiry and collaboration skills. This comparison could be done on a larger scale comparing these differences in IB schools and national curriculum schools in more than one country.

Despite the limitations, this study may contribute to a better understanding of individual preparation on knowledge gains and students' attitudes towards future collaborative tasks in IB schools. Furthermore, research in collaborative inquiry learning includes mainly low secondary students or University students; empirical work for high school students in IB schools is scarce. Although more exploration into the effect of individual preparation in CIL is necessary to be able to make recommendations for practice, the present study may contribute to future efforts of educators for the successful implementation of CIL in international schools' settings.

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Appendices

Appendix A
Name: ______________________________
START TIME: _________

Grade: ______________________________
END TIME: ___________

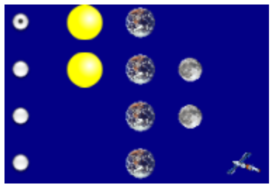
Gravity and Orbits

Learning Objectives- Students will be able to:

- Draw motion of planets, Moons and satellites.
- Draw diagrams to show how gravity is the force that controls the motion of our solar system.
- Identify the variables that affect the strength of the gravity.
- Predict how motion would change if gravity was stronger or weaker.

Part 1: Understanding motion

1) Open the ***Gravity and Orbits*** simulation. **Take 5 minutes** to **explore** how the Earth, Moon, and the Space Station move. Talk about what you find with your partner especially on what controls have you found?



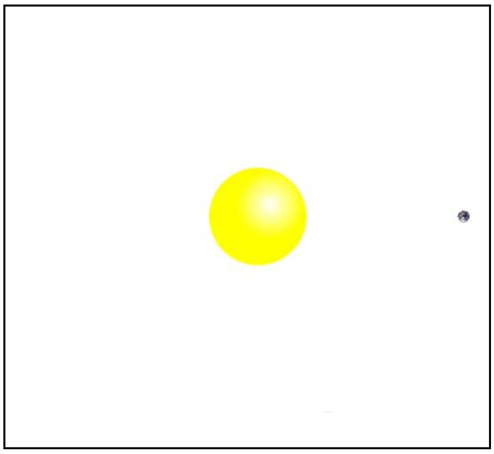
2) Compare the motion of the **Earth moving around the Sun** with the **Moon moving around the Earth**.
   If you and your partner each have a computer: Try choosing a different view on each computer for this question.

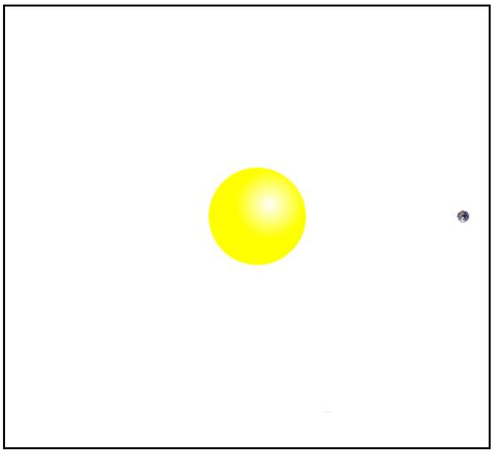
Earth moves around the Sun Your Picture Your Description	**Moon moves around the Earth** Your Picture Your Description
What are some things you find that are the **same** about these motions? What are some things you find that are **different** about these motions?	

Part 2: Understanding Gravity

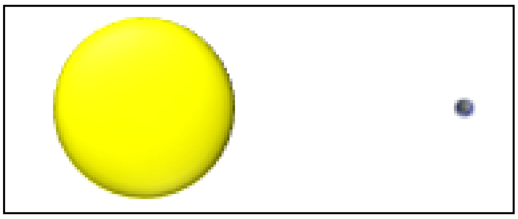
3) For the Sun and Earth system:
   Draw the path of the Earth with **Gravity ON** and **Gravity OFF**

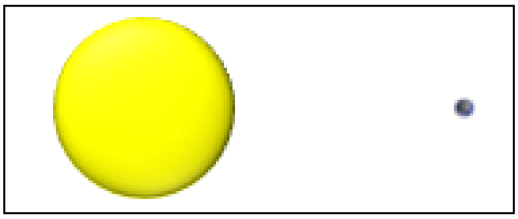
GRAVITY ON **GRAVITY OFF**





4) **Draw** the Sun's gravitational pull on the Earth **Draw** the Earth's gravitational pull on the Sun





TALK TO YOUR PEER: Why do you think the Earth moves, but the Sun does not move?

5) **Play** with the sim to find ways to change the length of the blue gravity force arrows. Collect your results in the table below.

a) Fill in an **ACTION** below and **write** whether or not the gravitational force increases or decreases.

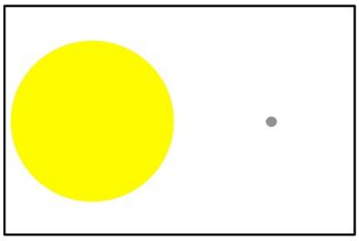
ACTION	Gravity Force Increases	Gravity Force Decreases
Put star and planet closer together		

b) What can affect the strength of gravitational force? What can you conclude from the results in your table?

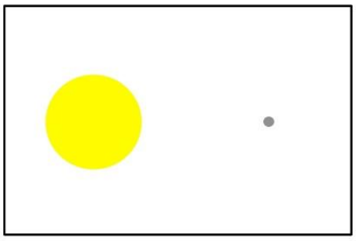
6) Comparisons:

a) **Compare** these two cases:

CASE 1



CASE 2

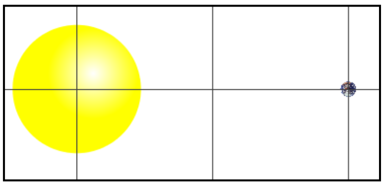


What was changed between Case 1 and Case 2?

Draw the force of gravity on the Earth in each case.

b) **Compare** these two cases:

CASE 1



CASE 2

What was changed between Case 1 and Case 2?

Draw the force of gravity on the Earth in each case.

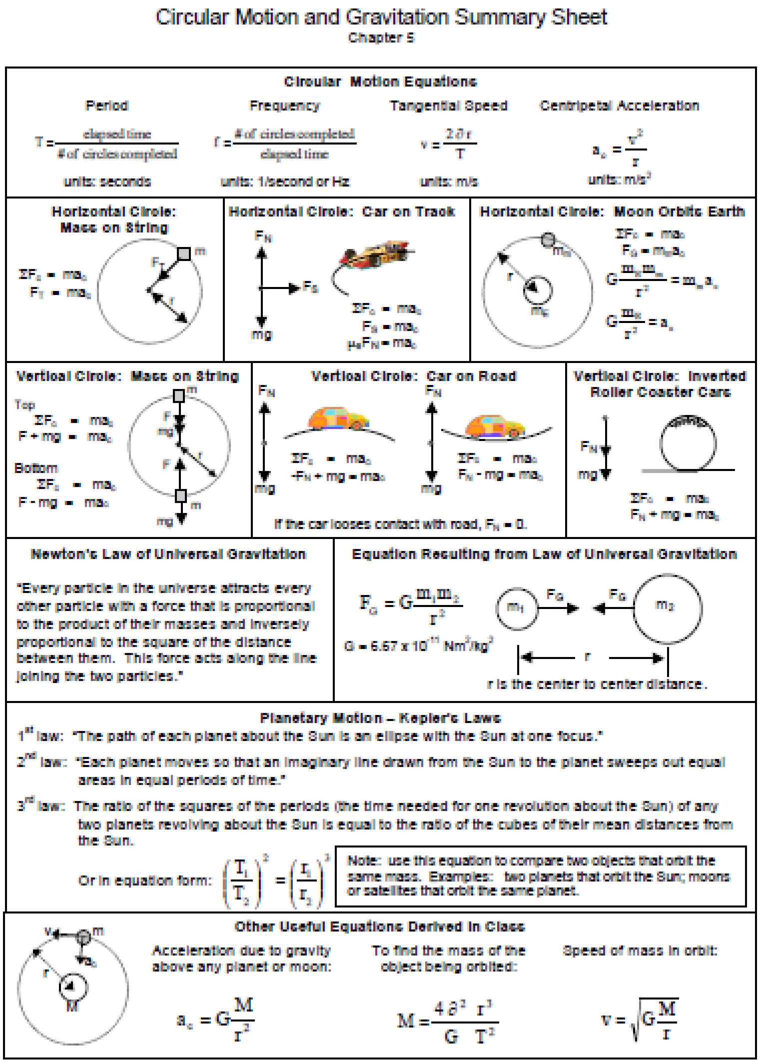
Part 3: Gravity and Motion

7) Fill in the table to help describe what you find out.

How can you….	Explain what you changed	Draw the motion paths	What other changes do you notice?

...make the Moon go around the Earth in a bigger circle?			
...make the Earth take more time to go around the Sun?			
...make the Earth take less time to go around the Sun?			

Appendix B



Circular Motion and Gravitation Summary Sheet
Chapter 5

Circular Motion Equations

Period	Frequency	Tangential Speed	Centripetal Acceleration
$T = \frac{\text{elapsed time}}{\text{\# of circles completed}}$	$f = \frac{\text{\# of circles completed}}{\text{elapsed time}}$	$v = \frac{2\pi r}{T}$	$a_c = \frac{v^2}{r}$
units: seconds	units: 1/second or Hz	units: m/s	units: m/s^2

Horizontal Circle: Mass on String

$\Sigma F_c = ma_c$
$F_T = ma_c$

Horizontal Circle: Car on Track

$\Sigma F_c = ma_c$
$F_s = ma_c$
$\mu_s F_N = ma_c$

Horizontal Circle: Moon Orbits Earth

$\Sigma F_c = ma_c$
$F_G = m_m a_c$
$G\frac{m_E m_m}{r^2} = m_m a_c$
$G\frac{m_E}{r^2} = a_c$

Vertical Circle: Mass on String

Top
$\Sigma F_c = ma_c$
$F + mg = ma_c$

Bottom
$\Sigma F_c = ma_c$
$F - mg = ma_c$

Vertical Circle: Car on Road

$\Sigma F_c = ma_c$
$-F_N + mg = ma_c$

$\Sigma F_c = ma_c$
$F_N - mg = ma_c$

If the car looses contact with road, $F_N = 0$.

Vertical Circle: Inverted Roller Coaster Cars

$\Sigma F_c = ma_c$
$F_N + mg = ma_c$

Newton's Law of Universal Gravitation

"Every particle in the universe attracts every other particle with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between them. This force acts along the line joining the two particles."

Equation Resulting from Law of Universal Gravitation

$F_G = G\frac{m_1 m_2}{r^2}$

$G = 6.67 \times 10^{-11}$ Nm^2/kg^2

r is the center to center distance.

Planetary Motion – Kepler's Laws

1st law: "The path of each planet about the Sun is an ellipse with the Sun at one focus."

2nd law: "Each planet moves so that an imaginary line drawn from the Sun to the planet sweeps out equal areas in equal periods of time."

3rd law: The ratio of the squares of the periods (the time needed for one revolution about the Sun) of any two planets revolving about the Sun is equal to the ratio of the cubes of their mean distances from the Sun.

Or in equation form: $\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{r_1}{r_2}\right)^3$

Note: use this equation to compare two objects that orbit the same mass. Examples: two planets that orbit the Sun; moons or satellites that orbit the same planet.

Other Useful Equations Derived in Class

Acceleration due to gravity above any planet or moon:	To find the mass of the object being orbited:	Speed of mass in orbit:
$a_c = G\frac{M}{r^2}$	$M = \frac{4\pi^2}{G}\frac{r^3}{T^2}$	$v = \sqrt{G\frac{M}{r}}$

Appendix C

Name: ____

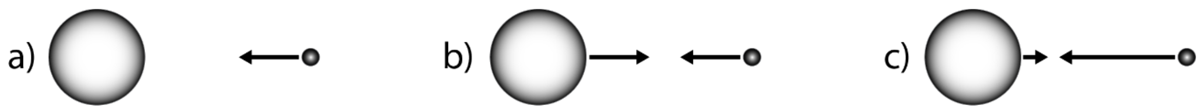
Grade: ____

Gravity and Orbits

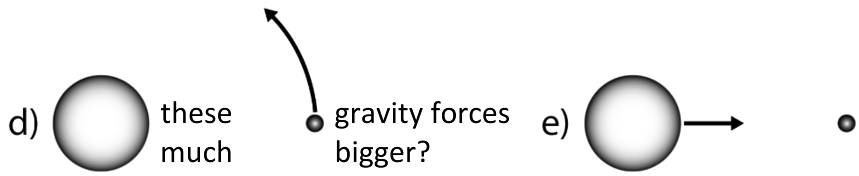
Pre-lab

1. Choose the picture you think shows the gravity forces on the Earth and the Sun.

(a longer arrow to represents a big force, and a shorter arrow represent a smaller force)



2. How would these gravity forces change if the Sun got much bigger?



Increase Stay the same Decrease

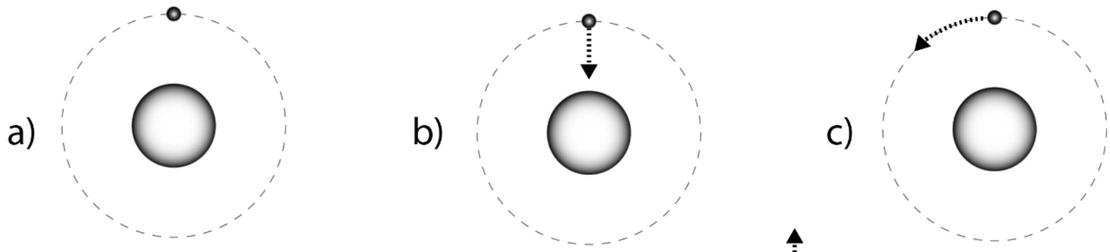
3. How would these gravity forces change if the Earth was much closer to the Sun?

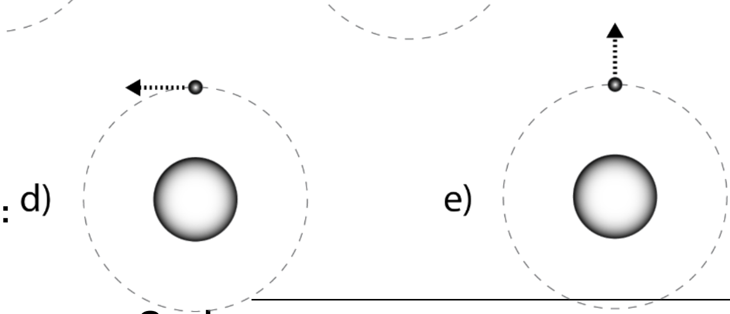
Increase Stay the same Decrease

4. How would these gravity forces change if the Earth got much smaller?

Increase Stay the same Decrease

5. Choose the picture of how the Earth would move if you “turned off” the gravity forces.





Appendix D

Name: ____

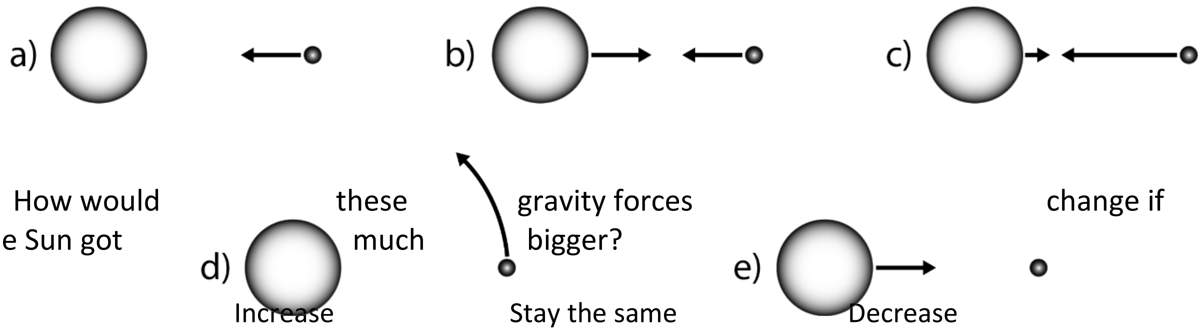
Grade: ____

Gravity and Orbits

Post-lab

1 Choose the picture you think shows the gravity forces on the Earth and the Sun.

(a longer arrow to represents a big force, and a shorter arrow represent a smaller force)



2. How would these gravity forces change if the Sun got much bigger?

Increase Stay the same Decrease

3. How would these gravity forces change if the Earth was much closer to the Sun?

Increase Stay the same Decrease

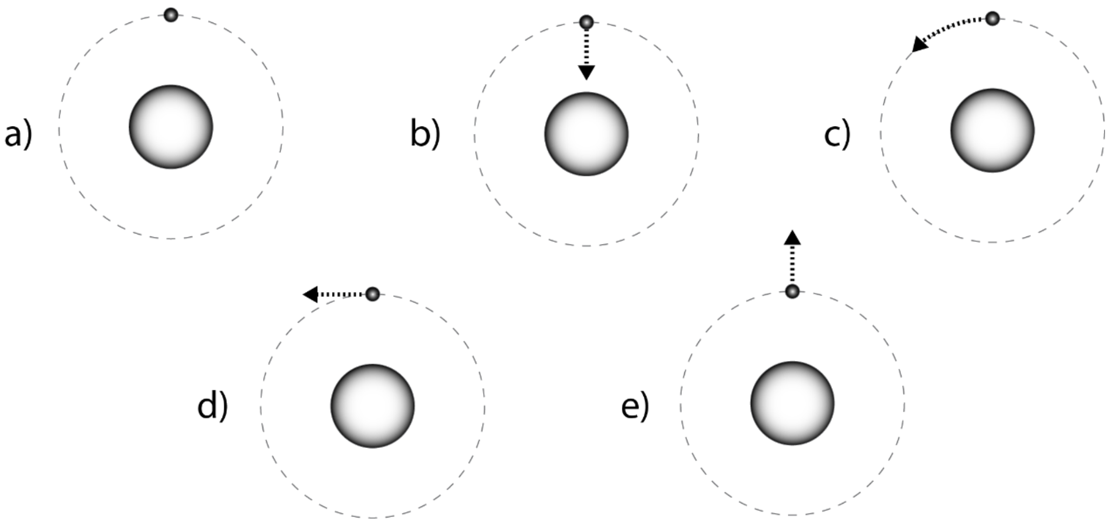
4. How would these gravity forces change if the Earth got much smaller?

Increase Stay the same Decrease

5. How would these gravity forces change if the Earth and Sun were moved far apart?

Increase Stay the same Decrease

6. Choose the picture of how the Earth would move if you “turned off” the gravity forces.



Appendix E

Delayed Test – Gravity and Orbit

Statement	True or false?
1. There is no gravity in space.	
2. Gravity only affects things on Earth.	
3. The Moon is a satellite.	
4. Gravity keeps the Moon orbiting around the Earth.	

1. The force of gravity between two planets depends on their
   A. masses and distance apart.
   B. planetary atmospheres.
   C. rotational motions.
   D. all of the above

2. If the masses of two planets are each somehow doubled, the force of gravity between them
   A. doubles.
   B. quadruples.
   C. reduces by half.
   D. reduces by one-quarter.

Page 1 / 2

3. If the mass of one planet is somehow doubled, the force of gravity between it and a neighboring planet
   A. doubles.
   B. quadruples
   C. reduces by half.
   D. reduces by one-quarter.

4. When you toss a projectile sideways, it curves as it falls. It will be an Earth satellite if the curve it makes
   A. matches the curved surface of Earth.
   B. results in a straight line.
   C. spirals out indefinitely.
   D. none of the above

5. When a satellite travels at a constant speed, the shape of its path is
   A. a circle.
   B. an ellipse.
   C. an oval that is almost elliptical.
   D. a circle with a square corner.

Appendix F
The questionnaire Evaluation Cooperative/collaborative learning

Today you have worked together with your group. You had to work together in inquiry task and everyone had to give his/her opinion about the task in order to solve it in a joint effort Below you see a few statements about working together (collaborative learning). For each statement you have to tick the most appropriate box. You have to indicate whether you disagree, more or less agree, or totally agree.

	Disagree	More or less agree	Totally Agree
Everyone listened to each other.	☐	☐	☐
All group members participated. For example, everybody helped giving ideas related to the questions and the solution.	☐	☐	☐
We quickly agreed on what our final conclusion should be.	☐	☐	☐
I liked it to work in a group on this assignment.	☐	☐	☐

Because we worked in a group, it was difficult for me to understand what we had to do. .	☐	☐	☐
By working in a group, I learned more than when I had to do the assignment alone.	☐	☐	☐
I think I have expressed my opinion well.	☐	☐	☐
I have introduced many explanations, meaning of words and arguments.	☐	☐	☐
We looked each other in the eye while working together.	☐	☐	☐
We let each other speak without interrupting.	☐	☐	☐
I have learned a lot from this assignment.	☐	☐	☐
We gave each other compliments on a regular base.	☐	☐	☐
We have considered the arguments of all group members.	☐	☐	☐
We first discussed how we would tackle the task.	☐	☐	☐
I found it scary to ask for help in the group.	☐	☐	☐
I am satisfied with our final conclusion about the task.	☐	☐	☐

I tried to understand what someone else meant.	☐	☐	☐