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EFFECT OF TEACHING AND LEARNING-SCRUM ON IMPROVEMENT PHYSICS ACHIEVEMENT AND TEAM COLLABORATION ABILITY OF LOWER-SECONDARY SCHOOL STUDENT

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Cai-Qin Han

Abstract: *Employers believe that people with the ability to work in teams can bring success to their business. Therefore, it is very essential to start cultivating students' teamwork skills in lower-secondary school to prepare students for the future. This study took "Physics in Bicycles" as an example to explore the effect of Teaching and Learning-Scrum (TL-Scrum) on students' physics achievement and team collaboration ability. It was conducted at a lower-secondary school in Changsha, China. "Physical Knowledge of Bicycles" Test and "Team Collaboration Ability" Measurement were applied to the two groups prior to and following the experiment. The experimental group (N=61) participated in TL-Scrum teaching, whereas the control group (N=58) participated without TL-Scrum teaching. The results revealed a significant difference between the two groups, with the experimental group learners performing better than the control group in the academic achievement. In addition, the results showed better positive effects of TL-Scrum on experimental group learners in team collaboration ability. Results suggested that learners achieved better academic achievements and team collaboration with the approach of TL-Scrum, which pointed to certain implications for physics teaching research, as well as in education of future physics teachers.*

Keywords: *lower-secondary school students, physics education, team collaboration, TL-Scrum*

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Introduction

With the continuous advancement of basic education curriculum reform in China (Ministry of Education, 2001, 2010), physics teaching should not only pay attention to students' mastery of knowledge and content, but also cultivate students' ability of solving problems, planning, working in teams, communicating, and reflecting (Sahhyar & Nst, 2017). Limatahu et al. (2018) described that learning physics is not just about remembering physical concepts as well as having the ability to discover themselves. Some physics teachers try to help students develop these abilities through team collaboration in their teaching. Fredrick (2008) believed that to develop students' abilities such as teamwork, teachers need to know what strategies students are already mastering and use new ones in the classroom. In fact, team collaboration is a model of learning that teachers use in their teaching (Ismail et al., 2019). It is a small group of people who work together as a way to achieve a common goal, thereby actively promoting student participation in the classroom (Davies, 2009). Teamwork is one of the most used skills in the workplace (OECD, 2020). At the same time, team collaboration abilities are also often considered to be the skills that employers are looking for in their employees at work. Many studies on collaborative learning have shown that it could help students develop good interpersonal and social skills, improve learning efficiency, and enhance classroom participation (Bruffee, 1999; Cross et al., 2005; Han & Son, 2020; Le et al., 2017). All of these abilities need to be accomplished through team collaboration. Ghavifekr (2020) stated that collaborative learning in the classroom could improve students' interpersonal and cognitive thinking skills. Hurst et al. (2013) found that collaborative learning positively affects students' academic performance and social skills. Olaniyan and Govender (2018) also proposed a goal-task collaborative learning and explored the goal-task collaborative learning to the performance of male and female students in upper-secondary school physics electricity. Johnson et al. (2008) argued that the main advantage of collaborative learning is that it builds students' confidence, motivates them

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to learn and maximizes their academic achievement. Many teachers felt that students need to learn how to work together so they can become problem-solving citizens (Pope-Ruark, 2012). Snyder (2009) argued that students need to learn how to work as a team. To teach students how to cooperate and enhance their team collaboration abilities, Pope-Ruark (2012) noted that using Scrum in college professional writing and rhetoric courses could develop these skills in students.

Scrum was formalized by Ken Schwaber and Jeff Sutherland in 1993 and it was initially utilized in software development (Schwaber & Sutherland, 2017). It is a framework that can help people solve complex problems while delivering the highest valuable products to those who are needed in an efficient and creative manner way, so as to improve teamwork, creativity, and team flexibility (Miller, 2008; Scharff, 2011). The three main principles of the model are mainly composed of transparency, inspection, and adaptation, supported by roles, artifacts, and events, and tested with artifacts to visualize the whole process (Schwaber & Sutherland, 2017; Scrum Alliance, 2016). In recent years, it has continuously penetrated into the field of education. Kingston (2015) described to the extent that creating a very good-looking manual in a 7th-grade math class combined with the entire process of Scrum advanced students' teamwork and motivation to learn. Ovesen (2013) believed that when applying Scrum to the industrial design courses in college, improved the focus and efficiency of the team, and the communication and attitude within the team improved significantly. Several other researchers (Baham, 2020; Magana et al., 2018; Werner et al., 2012) have introduced Scrum into software development courses in higher education, which enhances students' communicative skills as well as their teamwork skills. These studies refer to the need for higher education to explore more ways in which students could be involved in projects. Jurado-Navas and Munoz-Luna (2017) successfully applied Scrum to an English course in Malaga University to foster students' ability to think independently, enhance their critical and creative approach to knowledge and team collaboration ability. Vogelzang et al. (2019) found that applying Scrum in a chemistry concept class "Redox Reaction" improved students' motivation and academic achievement as well as cognitive and metacognitive awareness. Vogelzang et al. (2020) took the "Green Chemistry" as an example to explore the effects of Scrum on students' critical scientific literacy, which revealed that Scrum could deepen students' understanding of concepts and promote the development of critical scientific literacy. Xu et al. (2020) stated that the Scrum in bilingual teaching of chemical engineering could stimulate students' motivation and initiative and promote the development of students' teamwork ability.

Physics is often considered an abstract subject (Örnek et al., 2008; Otero & Finkelstein, 2010; Whitelegg & Parry, 1999), and due to its high level of abstraction and meticulous logic, students are overwhelmed by the learning process and experience a lack of motivation, less communication with others and weak self-learning ability. Scrum is a tool that facilitates visualization of the learning process (Sutherland & Sutherland, 2014) and improves students' enthusiasm and teamwork. It enables students to participate in the learning process through three roles, four events, and three artifacts (Scrum Alliance, 2016), which permit them to plan their learning goals, complete learning tasks together, and check the progress of others at any time and supervise their own learning. Scrum helps teams to set specific goals and gives students enough space to communicate, which is essential to building team collaboration abilities (Hocker & Wilmot, 2003).

TL-Scrum (Teaching and Learning-Scrum)

According to the application process of Scrum in software development, integrated with related research of Eduscrum (Delhij et al., 2015; Filho & Rui, 2018; Tudevdagva et al., 2020; Wijnands & Stolze, 2019), analyzed student perceptions when Scrum is applied to other subjects (Mahnic, 2010), concluding that Scrum has the following pedagogical advantages: this model could boost students' reflective skills, learning efficiency and communication skills, stimulate enthusiasm for learning, enhance team organization and collaboration, strengthen students' critical and creative thinking, supervise students' learning better, make the learning process transparent, give students constructive feedback (Vogelzhang et al., 2019; Magana et al., 2018; Opt & Sims, 2015; Pope-Ruark, 2011; Pope-Ruark, 2012). Therefore, to improve students' team collaboration abilities, the interdisciplinary teaching draws on the "agile development" approach in software development and innovatively introduces Scrum into physics teaching, and based on Scrum, constructs TL-Scrum (Teaching and Learning-Scrum), including the following six instructional stages: introducing task goals, building study groups, setting learning goals, checking study schedules, reporting learning outcomes, and reviewing learning process. The process of TL-Scrum in learning is shown in Figure 1.

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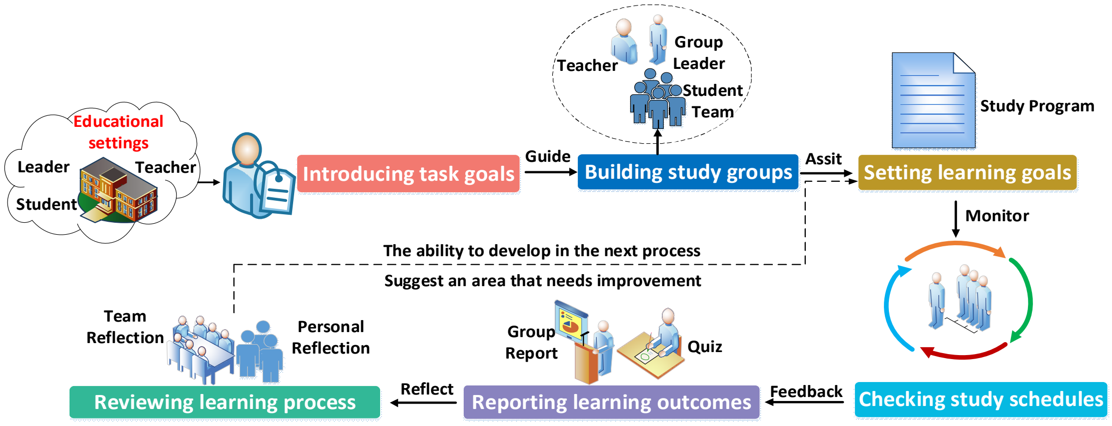
Figure 1
Workflow of TL-Scrum (Teaching and Learning-Scrum)



Stage 1: Introducing task goals

This stage involves the teacher introducing the goals of the task to the students based on the course content and leaders' requirements. In accordance with the basic idea of the "Golden circle"(Sinek, 2011): why-how-what, used to clarify the purpose of this task to students; when the goals are clear, students can know the methods better; only in this way will the expected result appear.

Stage 2: Building study groups

At this stage, the teacher will hand out a grouping form of the students, who fill it out according to their situations, and give it to the teacher immediately. The teacher looks at what students have accomplished and uses it as a basis for selecting a student to lead the class. The team leader's first task is to set up a study group, and anonymity is used to ensure that the grouping is conducted in the same gender or too close to each other, and so on. The adoption of anonymity creates a relatively unfamiliar learning environment, enabling students to become more relaxed and communicate more effectively with others. Team members work together to complete tasks with unique team rules and group names to enhance team cohesion and give students a sense of belonging, thus stimulating their interest in learning and promoting motivation. In the meantime, team members need to define "done" and "fun" that everyone needs to agree.

Stage 3: Setting learning goals

At this stage, the group formulates learning goals by discussing and incorporating the characteristics of the group, or consulting with the teacher, and prioritizing tasks. In the process of discussing with others-you can engage your thinking and promote self-regulation. The team leader assigns tasks according to the characteristics of the team members, and each member has his unique tasks. The teacher should help students use the bulletin board properly and update it quickly. The format of the bulletin board is composed of four columns: 1) name; 2) tasks to be done; 3) tasks being done; 4) tasks already done. The bulletin board allows students to view the study schedules of others at any time. When problems are encountered, team members can negotiate together to resolve them and achieve their ultimate goal. Through tasks, students set specific goals, which are important for the promotion of team collaboration (Hocker & Wilomot, 2013).

Stage 4: Checking study schedules

During this session, team members discussed and answered the three questions asked by the team leader: 1) What learning tasks did you complete? 2) What problems did you come up with? 3)What do you want to learn next? Each student answers these three questions, leading the students in the right direction. Immediately following this process, the bulletin board is updated and the sticky notes for the learning tasks are placed in the "tasks being done" sections of the bulletin board. When a task is completed, the sticky notes will move to the "tasks already done" column. This stage promotes effective communication among team members by answering the three questions proposed by the team leader, which can promote team collaboration (Fredrick, 2008).

Stage 5: Reporting learning outcomes

The reporting stage is a demonstration of what students have accomplished during this period, and everyone is required to speak on a platform as a way of examining their oral and impromptu acting skills. At this stage, one

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group is asked to state the results of the discussion and the other group gives their opinion. The teacher listens attentively to the students' reports on this process and puts forward constructive suggestions when necessary and conducts random tests. The learning group reporting must ensure that everyone learns the content of this module. When reporting, the group arranges a good division of labor, and when one person has a problem during reporting, other members should make timely additions. Group members should be aware that reporting learning outcomes are the result of the collective wisdom of the group members. Before reporting learning outcomes, they communicate with each other and ask for help or help others with tasks. For the members of the team, it is not only necessary to have the individual ability, but also the ability to do their best and coordinate in different positions.

Stage 6: Reviewing learning process

This stage is devoted to thinking about the implementation process, whether as a group or as an individual. Students reflect on how they collaborated with each other, how they could have completed the learning task faster, and which parts of the process went wrong. Team reflection at least suggests areas that need to be improved in the next process. Team reflection is to examine the collaboration among team members to better accomplish the task, which is necessary to enhance team collaboration. Personal reflection mainly answers "What abilities have you demonstrated in this process and what abilities should be developed in the next process", to promote your ability.

Research Focus

Based on the above research, it can be understood that TL-Scrum is a new teaching in which students work together to complete tasks, stimulate students' interest in learning, promote the development of students' overall ability, and it is a kind of active collaborative learning (Delhij et al., 2015). The purpose of this study was to try to integrate TL-Scrum into the lower-secondary school physics class by selecting "Physics in Bicycles" as the teaching material, implementing and designing the teaching. By comparing with conventional physics teaching, relevant data were collected to quantitatively analyze the feasibility of TL-Scrum in lower-secondary school physics teaching. Accordingly, the following research questions were suggested:

1. Does TL-Scrum have an effect on lower-secondary school students' physics academic achievement?
2. Is TL-Scrum effective in enhancing lower-secondary school students' team collaboration ability?

Research Methodology

General Background

This study was a quasi-experimental one with an experimental and control group pre-test and post-test design. Due to the different characteristics of the experimental and control groups, students were not randomly selected (Creswell & Creswell, 2018); instead, the two classes taught were assigned as experimental group and control group (Fraenkel & Wallen, 2008). The control and experimental groups were tested before and after the experiment by the physical knowledge of bicycles test. The team collaboration ability measurement was administered to the experimental group before and after only. The experimental group participated in the TL-Scrum teaching, while the control group did not. This study was carried out in the spring semester of 2021 among ninth grade students in a lower-secondary school in Changsha, Hunan, China. The same teacher taught all control and experimental groups and provided the same content to these groups. Table 1 presents the research framework.

Table 1
Research Design

Group	Pre-test	Intervention	Post-test
Experimental	O_1	X_1	O_3
Control	O_2	X_2	O_4

Notes:
O1 and O3: "Physical knowledge of bicycles" test and "Team collaboration ability" measurement.
O2 and O4: "Physical knowledge of bicycles" test. X1: TL-Scrum teaching; X2: Conventional teaching.

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Sample

A total of 119 students in Grade 9 from a lower-secondary school in Changsha, China, were enrolled in this research. There were 27 boys and 34 girls in the experimental group; 31 boys and 27 girls in the control group. Among these participants, there were 58 boys and 61girls, with an average age of 15.0. The proportion of boys (48.8) and girls (51.2) was at about the same level. All students volunteered to participate in this research. Participants were informed about the research methodology and required to sign consent forms before the research.

Data Collection Instruments

Physical Knowledge of Bicycles Test

In physics education of Chinese ninth graders, the module of "Physics in Bicycles" is usually taught in the ninth grade. Some of the content was presented in eighth grade, including mechanics, acoustics, and optics. For their future studies, it is crucial to know what physics is embedded in the bicycle and give examples.

Students' performance was tested through a pre-test and post-test. The pre-test used the results of the weekly courses about bicycles. The post-test was designed as an assessment of 15-bicycle physics questions to evaluate students' knowledge of "Physics in Bicycles". Among these questions, Q1-Q10 were multiple-choice questions while questions Q11-Q15 were fill-in-the-blank. Pre-test and post-test questions were identical in the experimental and control groups. One sample of a multiple-choice question was:" Bicycle is a familiar means of transportation, from the structure and use of the bicycle, it involves a lot of knowledge about friction. Which of the following statements is true?" And the choices were pinch the brakes and do not push the bike on the horizontal ground because the push force is less than the friction force, tires with tread pattern is to reduce friction by changing the roughness of the contact surface and the brake is squeezed by increasing the pressure to increase the friction of the brake handle. One sample of a fill-in-the-blank question was: "The bicycle parked on the roadside is____(fill in "motion" or "stationary") relative to the motorcycle running on the road. The pattern on the handlebars is to____(fill in "increase" or "reduce") friction." Some of the questions in the before and after tests were the same, but the order or options were disrupted.

Team Collaboration Ability Measurement

A 5-point Likert scale was used to analyze whether TL-Scrum could enhance the teamwork ability of students (see Appendix 1). The reliability of the scale pre-posttest was estimated by Cronbach using alpha coefficients of .890 and .803, respectively. It shows that the pre-post test results tested for this study were sufficiently consistent. Within the entire questionnaire, there are 24 items assessing students' team collaboration abilities, with 5 items (Q1-Q5) towards participation, 5 items (Q6-Q10) towards communication, 4 items (Q11-Q14) towards cooperation attitude, 5 items (Q15-Q19) towards overall awareness and 5 items (Q20-Q24) towards cooperation ability. Each positive statement was scored as 1 (completely disagree), 2 (strongly disagree), 3 (fair), 4 (strongly agree), and 5 (completely agree); negative statements scored the opposite.

Procedures

The research started in January 2021 and lasted for four months. During these months, through continuous implementation and revision of Scrum, "the physical knowledge of bicycles" was eventually selected as teaching material to design and implement teaching in TL-Scrum. According to the curriculum standards of the Ministry of Education (MOE) in China, the goal of "Physics in Bicycles" is: 1) To know the structure of a bicycle and describe its structure and function. 2) Understand what physical knowledge has been used in bicycle design. 3) Apply what they have learned and drift a research paper.

In China, the "Physics in Bicycles" has been introduced in the first semester of Year 8 in the module of sound phenomena, for example, students were asked to know how the bicycle bell is produced. Before this, students may have used a bicycle in their lives and were familiar with it. This is followed by an understanding of its use in terms of light phenomena, mechanics, and thermodynamics. Students need to understand that the physics of a bicycle includes its use in mechanics, thermodynamics, optics, electricity, and acoustics. While in Year 10 (upper-secondary

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school) physics teaching, the bicycle is a common case for explaining various physics knowledge, and the various aspects of the bicycle's structure could help us to learn physics knowledge more visually. Thus, reflecting the concept of moving from life to physics and from physics to life. Based on this situation, the "Physics in Bicycles" was chosen as a learning material for TL-Scrum.

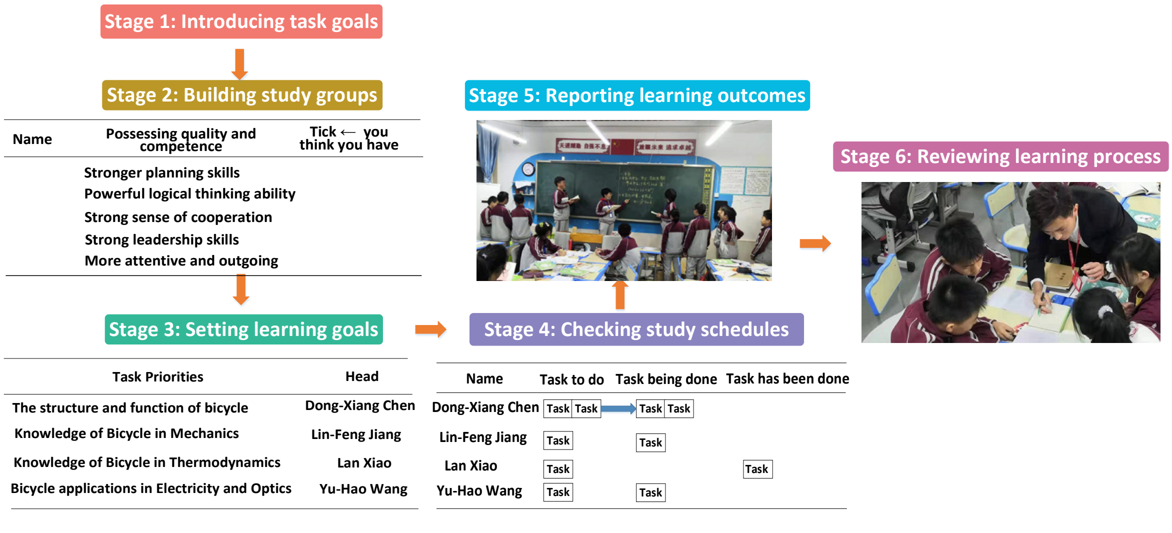
During the first month of the semester, both groups of students used conventional teaching, that is, the teacher elaborates the knowledge in the classroom, while the students sit and listen carefully to the teacher. This study was conducted in four 40-minute lessons in both the experimental and control groups, which were divided into three main phases.

Phase 1: Before the study began, two equal-level classes were chosen as control and experimental groups. Subsequently, the two groups were pre-tested and ensure that they were homogeneous in lesson 1. For the pre-test, both the control and experimental groups were limited to 15 minutes to complete.

Phase 2: Students from the two groups learned the same content, namely, learned the structure of a bicycle and described its structure and function, and understood what physical knowledge has been used in bicycle. In lesson 2 to 3, the teacher in the control group used conventional teaching, that is, students collected relevant information on their own to summarize the physics knowledge in bicycles, and then the teacher would summarize and conclude the content in class according to the students' completion and complete the corresponding exercises. While the teacher in the experimental group used TL-Scrum to complete the teaching of "Physics in Bicycles" (Figure 2). In lesson 2, the teacher introduced the learning task to the students, organized them into learning groups, and guided them in setting learning goals. In lesson 3, the teacher checked the students' schedules and gave guidance when necessary. The students worked in small groups to report on their learning results, and finally the students reflected on the whole learning process.

Phase 3: At the end of the course, the students completed a post-test between the two groups and a questionnaire was given to the experimental group only in lesson 4. The post-test must be completed within 25 minutes. Students' learning gains were analyzed and compared based on the pre-test and post-test, while the students' questionnaire was used to analyze the influence of TL-Scrum on the team cooperation ability of the experimental group.

Figure 2
Experimental Group Using TL-Scrum Teaching



Techniques of Data Collection

Two data collection methods were used in this research, including tests and questionnaires. Before collecting the data, the source of the data was identified followed by the type of data, the technique of data collection, and instrument used (Mundilarto & Ismoyo, 2017). For assessing students' academic achievement, a post-test was conducted to both groups of students at the end of the course; in order to assess students' teamwork skills, a post-

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test was conducted at the end of the course to students in the experimental group only (with 61 questionnaires distributed and 55 questionnaires finally returned). As can be seen in Table 2.

Table 2
Technique of Data Collection

Data Source	Data Type	Data Collection Technique	Instrument
Students	Academic Achievement	Pre-test and Post-test	Ten Multiple-Choice Test Five Fill-In-The-Blanks
Students	Team Collaboration Skill	Pre-test and Post-test	Twenty-Four Items Test

Data Analysis

The pre-test and post-test data on academic achievement and team collaboration abilities were conducted by SPSS (Statistical Package for the Social Sciences). The reliability of the scales was determined using Cronbach's alpha coefficients. Basic descriptive statistics (mean M, standard deviation SD) were calculated for the numerical variables. An independent sample t test was used to analyze the differences between the pre-test and post-test of academic achievement, while the paired sample t test was used to analyze the difference in teamwork ability between the pre-post and post-test in the experimental group. Additionally, the sign level of the independent sample t test and the paired sample t test was set at p =.05 in this study.

Research Results

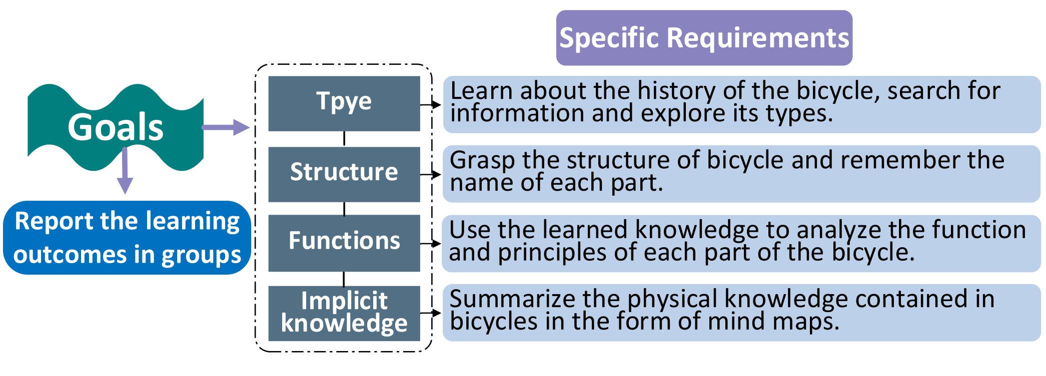
Learning Process

From the curriculum standards of the Ministry of Education (MOE) in China, it is clear that the objectives of "Physics in Bicycles" require students to complete two parts. The first is to investigate what physics is contained in a bicycle and summarize it. The second part is to write a research report based on it. Based on the TL-Scrum, these parts were completed in the following stages.

Stage 1: Introducing task goals

In this stage, the teacher introduced the task objectives to the students, which is to explore physics knowledge in bicycle. The specific content was the structure, types and characteristics of bicycles, as well as exploring what kind of physics was actually embedded in bicycles. The specific requirements were that the students worked cooperatively to complete the task and reported their learning to the class as a group. The learning tasks are shown in Figure 3.

Figure 3
Learning Tasks



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After introducing task goals, then the teacher asked students to think about and put questions to students.

Stage 2: Building learning groups

When the task objectives were described, under the guidance of the teacher, students were divided into different teams according to their personalities, including the brave team, the team that likes physics, and the team that cares about others. Afterward, based on the grouping table (Figure 2, Stage 2), the teacher selected team leaders, who set up a learning team of about 4-5 students and formulated the rules for group learning. Students from different teams were grouped to form multi-purpose groups, no matter which team or students need to master all the content. For example, there were four members in the first team, including a strong leader, a strong planner, a very active and outgoing person, and a person who likes physics very much. These students combined their characteristics to give the group the name of the "nothing to fear" team. The definition of "fun" is to play a mini-game between classes after every period of study; the definition of "done" is that all the team members have learned the content of the module and can explain the rationale behind it.

Stage 3: Setting learning goals

At this stage, students were required to find out what to do and what knowledge they needed to achieve a learning goal. The knowledge required to resolve the tasks assigned by the teacher was the concept of force, the relationship between force and motion, simple machines, optics, and electricity knowledge. Taking into account the characteristics of the group members, through discussion, the division of the students was as follows (Figure 2 Stage 3):

Student 1 focused on observing the bicycle, collecting pictures of the whole or parts of the bicycle, and understanding the structure and function of the bicycle parts.

Student 2's task was to explore the mechanics knowledge of bicycles.

Student 3 was to explore the bicycle's knowledge in thermodynamics and acoustics.

Student 4 was mainly to sort out the bicycle's knowledge in electricity and optics, and the priority of the tasks was determined according to the difficulty of the tasks.

After everyone has a clear learning task, the students' group would finish the bulletin board in time, so that the group could make clear the learning tasks of others.

Stage 4: Checking study schedules

In this stage, the teacher urged students to collect relevant information to handle the task at hand. If any student is confused or has no idea, the teacher would give guidance to orient students to identify the problem and solve it. By searching for information, group members answered each of the three questions raised by the team leader (Figure 2 Stage 4). At the end of the process, the teacher reminded students to move the "sticky note" and update the bulletin board. See Appendix 2 for the dialogue among students. The stage of checking study schedules is the student's perception of self, viewing the bulletin board, monitoring self-learning, stimulating intrinsic motivation, increasing interest in learning, self-regulation, and self-direction by asking the teacher, all in a team.

Stage 5: Reporting learning outcomes

In the reporting stage, the first group presented their learning (see Appendix 3), while the other group made comments on it (Figure 2, Stage 5). The first group was selected as all groups have the same learning tasks. The teacher helped the students to improve their learning tasks by making suggestions on what to report during the reporting process. Figure 4 presents the mind map of "Physics in Bicycles" by students.

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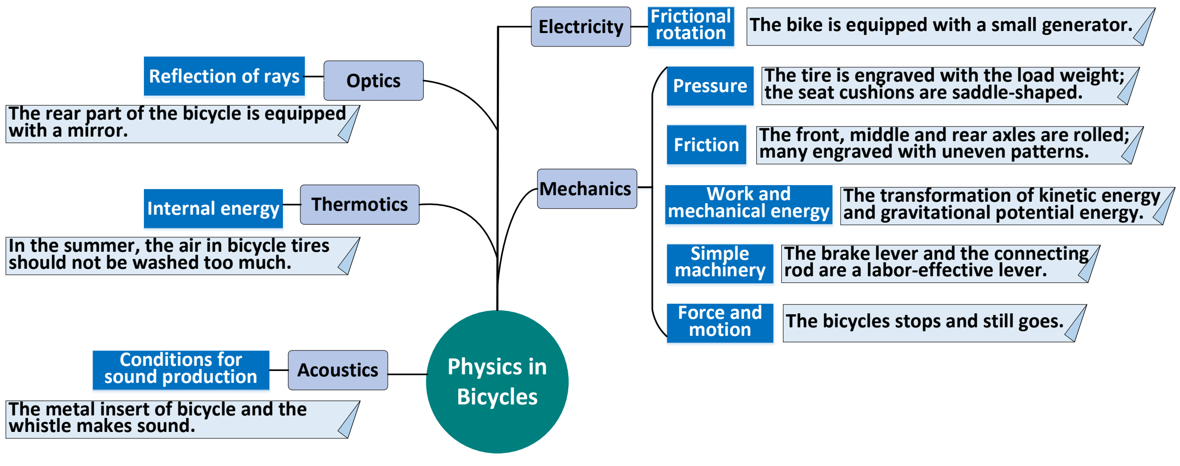
Figure 4

A Mind Map Showing the Physics in Bicycles



Stage 6: Reviewing learning process

At this stage, under the direction of the teacher, the group leader leads the group to review the learning process (Figure 2 Stage 6). Through reflection, students identified their problems in the process of learning. For example, a few students like chatting, solving problems and speaking without initiative; most students thought that they had learned a great deal from others and their mastery of the knowledge than when they studied alone. At the same time, the students also carefully reviewed and reflected on the problems of the group, such as our learning efficiency was high and the group leader's leadership ability was strong; communication within the group needed to be improved, and some problems could be solved quickly, which will take a lot of time; the knowledge have not been summarized and organized well, so they need to be supplemented constantly.

Effect of TL-Scrum on Students' Learning Achievement

To address the problem of whether there are significant differences in academic achievement between the experimental group and control group, an independent sample t tests were carried out. The pre-test and post-test results for the experimental and control groups (see Appendix 4) are shown in Table 3. The pre-test scores of the experimental group (M = 51.05, SD = 15.52) were higher than the control group (M = 47.17, SD = 15.31). There was no significant difference in the pre-test between the two groups (p =.17 >.05) and participants came from two parallel classes with similar levels of the knowledge base.

Table 3

Independent Sample t Test Results of the Experimental Group and Control Groups' Academic Achievement

Item	Group	*M*	*SD*	*F*	*t*	*df*	*p*
Pre-test	Control	47.17	15.31	.01	1.371	117	.17
	Experimental	51.05	15.52				
Post-test	Control	51.31	14.42	.47	3.389	117	<.05
	Experimental	60.80	16.04				
Gain score	Control	4.14	6.86	1.08	4.064	117	<.05
	Experimental	9.75	8.12				

As seen in Table 3, the post-test scores of the experimental group (*M* = 60.80, *SD* = 16.04) were higher than the control group (*M* = 51.31, *SD* = 14.42). The gain scores of the experimental group (*M* = 9.75, *SD* = 8.12) were

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also higher than the control group (*M* = 4.14, *SD* = 6.86) and there was a significant difference (t = 4.064, $p < .05$) between the two groups. Generally speaking, the experimental groups' performance is better than that of the control group. These results suggested that TL-Scrum is effective in improving students' academic achievement.

Effect of TL-Scrum on Students' Team Collaboration Ability

For the second research question, the paired sample t test was used to determine whether there was a significant difference between the teamwork ability of students in the experimental group of the pre-test and post-test. The students in the experimental group scored better in the post-test than in the pre-test within five sub-scales, namely, improving participation, boosting communication skills, correcting cooperative attitudes, enhancing collaboration skills, and strengthening overall awareness. On the whole, the average score of students' overall collaboration level in the experimental group changed from $M = 3.55$ to $M = 4.00$ (an increase of 0.45; $t = 7.34$; $p < .05$). Based on the results of the paired t test, students in the experimental group scored significantly higher using TL-Scrum teaching compared to the pre-test. As seen in Table 4.

Table 4
Paired Sample t Test Results of the Experimental Group and Control Groups' Team Collaboration Abilities

Sub-Scales	Item	*M*	*SD*	*t*	*df*	*p*
Improving participation	Pre-test	3.47	0.60	4.29	33	<.05
	Post-test	3.92	0.59			
Boosting communication skills	Pre-test	3.68	0.51	4.49	33	<.05
	Post-test	4.01	0.51			
Correcting cooperative attitudes	Pre-test	3.41	0.44	5.12	33	<.05
	Post-test	3.88	0.51			
Enhancing collaboration skills	Pre-test	3.56	0.38	5.84	33	<.05
	Post-test	4.04	0.46			
Strengthening overall awareness	Pre-test	3.63	0.44	6.06	33	<.05
	Post-test	4.08	0.41			
All Sub-Scales	Pre-test	3.55	0.29	7.34	33	<.05
	Post-test	4.00	0.42			

Discussion

Discussion on the Effect of TL-Scrum on Students' Learning Achievement

The research results confirmed that TL-Scrum teaching has a significant positive impact on students' academic achievement. TL-Scrum improves students' academic performance, which may be because students must systematically sum up previous knowledge and concepts to deepen their mastery and understanding of knowledge when solving learning tasks. Preliminary research (Magana et al., 2018; Scott et al., 2016) found that students' academic achievements were significantly improved by participating in Scrum teaching. This study showed that students could acquire knowledge and skills in the learning environment provided by TL-Scrum, which is helpful to developing their comprehensive abilities as well as promoting their academic achievements.

In this study, TL-Scrum aims to teach students to master "Physics in Bicycles" through team cooperation. This learning material is part of a comprehensive practical activity course, which should be in line with students' interests, and combine their needs, motives, and interests in a way that makes learning enjoyable. Studies have shown that in the evaluation of "Physics in Bicycles", the average score of the experimental group ranges from M = 51.05 to M = 60.80, with significant differences between the experiment and control groups. Vogelzang et al. (2019) explored the effects of Scrum teaching on the chemistry concept of 9th-grade students and found that it

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improves students' academic achievement and learning motivation. TL-Scrum emphasizes students' participation in classroom by adopting ability grouping form and effective supervision of learning. Vogelzang et al. (2020) also discussed the effects of Scrum implementation on students' critical scientific literacy in lower-secondary school chemistry classes, and research showed that the implementation of Scrum enhanced students' understanding of the concept of green chemistry and helped improve their academic performance. In TL-Scrum, reviewing learning process, reporting learning outcomes, and checking study schedules and other stages may be conducive to students master and understand knowledge, promote the application of knowledge, and improve academic performance. Dinis-Carvalho et al. (2019) found that the use of PBL (project-based learning) in Scrum improves students' academic performance and shows that PBL can strengthen the extent to which students perceive the learning task and form goal-oriented learning. TL-Scrum teaching provided students with the opportunity to communicate with the group and think independently on an individual basis, aiming at cultivating students' relevant skills, such as communication, independent thinking and problem solving, which have a substantial impact on their academic achievement. In future research, TL-Scrum can be combined with other learning strategies as a better way to enhance students' understanding and improve their academic achievements.

Discussion on the Effect of TL-Scrum on Students' Team Collaboration Ability

The study revealed that students were able to improve their average scores on team collaboration abilities after implementing the TL-Scrum teaching. Further analysis showed that students' scores have been improved in terms of increasing participation, correcting cooperative attitudes, improving communication skills, enhancing cooperation skills, and strengthening overall awareness.

In this study, TL-Scrum teaching was a self-regulated and self-directed process by building study groups, checking study schedules, and other learning activities that allow group members to negotiate, discuss, and think together. In fact, self-regulated and self-directed learning is included in team collaboration, which is a kind of bilateral learning. ROGIT (2020) believed that learners can learn to think about their own thought processes and use their learning strategies to help them adapt to learning. Numerous studies have shown that the process of self-regulation is an active and constructive process in which students regulate and observe their behavior, motivation, and cognition based on the goals they identify in the learning process (Bacharach et al., 2008; Pintrich, 2000; Zimmerman, 2008). In teamwork, they control and direct their behavior through cooperation, take responsibility for their learning, and make adjustment. At the same time, each student in the group was asked to report on their learning in class. When one group reported, another group made comments and questioned their report, and the group made judgments through analysis and reasoning after receiving the challenge, reflecting the students' critical and creative thinking. The reviewing stage taught students to evaluate and adapt their individual and team collaboration skills, triggered them to work better together, and subconsciously improved their team collaboration.

According to Opt and Sims (2015), Scrum provided students with the need for collaboration and helped to develop collaborative team skills that will serve them well in their future courses and careers. The TL-Scrum in this study created a positive learning environment for students and provided collaborative needs through a series of learning activities that facilitated communication with others. Brainstorming in team discussions triggered self-reflection, which gave rise to ideas that encouraged students' motivation and interest in physics, as well as curiosity and a strong desire to learn. The main purpose of reviewing phase was to improve teamwork, where students reflected on their collaboration with each other, how they could have completed the learning tasks faster, what went wrong and whether their efforts met their definition of "done". Bilingual teaching of chemical and engineering under Scrum could make students discover problems independently, boost students' motivation, and develop students' teamwork ability (Xu et al., 2020). When building a group, it was required to share their team experience with other members and developed team rules to enhance team cohesion, gave students a certain sense of belonging. Mahalakshmi and Sundararajan (2015) found that using Scrum in a collaborative web-based learning environment improved students' abilities such as teamwork and self-learning. TL-Scrum teaching emphasizes student participation, discussion, and completion of learning tasks through collaboration. All six instructional stages include continuous communication and discussion among students. But the discussion with group members' opinions may diverge, and it is possible to come up with new ideas by reasoning, analyzing, and developing an independent perspective, which is a form of critical and creative thinking. And the learning outcomes derived from teamwork, which is continuously explored to stimulate students' interest in learning and thus accomplish their tasks better. The combination of Scrum and cooperative learning encouraged communication among team

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members and emphasized active collaboration to promote teamwork, communication, and problem-solving skills (Magana et al., 2018; Pope-Ruark et al., 2011). Mahnic and Rozanc (2012) showed that students considered teamwork and communication among team members to be essential aspects of Scrum. Team members brainstormed what was necessary to complete each task during the stage of setting learning goals, resulting in a unique task for each team. The research of TL-Scrum showed that communication and collaboration among students are present throughout the teaching and learning process. And several scholars have found that using Eduscrum is beneficial to developing group work and a sense of responsibility and improving teamwork ability. It is a collaborative learning strategy that enhances student engagement (Filho & Rui, 2018; Verticchio & Soares, 2020). With the TL-Scrum teaching, students solved learning tasks through group cooperation, and using their scientific knowledge to summarize, organize, and report their results. Students reflected on their collaboration so that they could work together better and complete learning tasks better the next time.

Conclusions and Implications

This study presented TL-Scrum teaching in "Physics in Bicycles" and explored its effect on students' academic achievement and teamwork skills. In the first research question, this study aimed to investigate whether the implementation of TL-Scrum on students' achievement will help us better understand the effect of TL-Scrum on teaching and serve as an authentic reference for integrating TL-Scrum into other subjects. The results showed that the experimental group had better academic performance than the control group. The second research question was intended to investigate the effects of TL-Scrum on students' teamwork abilities. A questionnaire was given to 61 students in the experimental group. From the results of the questionnaire, most of the students believed that the use of TL-Scrum in physics teaching had a positive effect on their teamwork. Additionally, the students claimed that using TL-Scrum in the class has many benefits, including strengthening class participation, promoting cognition and metacognition, increasing learning motivation.

Despite the encouraging results with significantly different effects between the experimental group and the control group in the present research, limitations exist in the research design. On the one hand, this research only compared the effects of TL-Scrum with that of conventional teaching. It could not provide evidence to identify whether TL-Scrum has some positive effect on physics teaching. On the other hand, this present research only administered questionnaire to students in the experimental group before and after the implementation of TL-Scrum, which was to explore the effect of TL-Scrum on student teamwork. Therefore, it is not clear how students view the difference between TL-Scrum and conventional teaching. In the future, the teacher could devote some time and effort to reflect on the "Reviewing" phase of the learning process, so as this teaching can improve students' reflective skills more effectively. Finally, it is important to explore the possibility of applying TL-Scrum to other types of physics courses, such as new courses and experimental classes to provide a new way of physics teaching.

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Declaration of Interest

Authors declare no competing interest.

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Appendix 1
Teamwork Ability Scale

Items
1. In the course of the activity, I can keep completing the task.
2. I am actively involved in team activities.
3. I can integrate into the team and continuously improve team cohesion.
4. I can solve problems independently in teamwork.
5. I always have a hard time getting along with the people around me.
6. I will give some constructive advice on the views expressed by others.
7. I can find a way to mediate the disagreements and conflicts.
8. I have a tacit understanding of work cooperation with my peers.
9. I am polite and friendly to my teammates.
10. When a team encounters a bottleneck, I can find a solution.
11. When I communicate with others, I listen carefully to each other's conversations.
12. In teamwork, I actively share ideas with my peers.
13. I use good communication skills to help group members.
14. I continue to share experience and experience to promote the progress of the team.
15. I take the initiative to be responsible for the team and avoid problems.
16. If necessary, we will assign members' team roles based on their strengths.
17. I think the ability to cooperate is very important for a team.
18. We discuss the implementation of the agreement frankly and accurately.
19. We created a detailed task list and assigned the work tasks to the team members.
20. In the team, I will selflessly share my information and resources.
21. In teamwork, I understand and take the advice of others.
22. I can consider other people's opinions comprehensively in teamwork.
23. I can respond in time and discuss actively during the event.
24. As needed, I will organize expressions to make ideas easier for others to understand.

Appendix 2
Student activity of "checking study schedules"

Student 1: Let's stop what we are doing and answer three questions in turn: "What learning tasks have you completed during this period of time? What problems have you had? What are you going to study next?"

Student 2: I just collected some pictures of bicycles on the Internet, both overall and partial. I got a clear idea of what parts a bicycle consists of and looked up the types of bicycles, including mountain bikes, road bikes, mountain bikes, track bikes, and so on. The problem I encountered was that the function of the bicycle parts was not clear. Next, I plan to discuss with other students in the group or consult reference books and list the functions of each part in details.

Student 3: My task was to explore the design of the bicycle in terms of mechanics. I combed through the mechanics I had learned in the second book of grade 8, namely basic forces, pressure, work and energy and simple machines.

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My problem is that there was a lot of knowledge applied to mechanics, and I need the help from others. The next step is to analyze the various parts of the bicycle in relation to their application in mechanics.

Student 4: I was quite familiar with the thermal knowledge of the ninth grade, but I have less knowledge of the thermal part. In addition, knowledge of acoustic is simpler. At present, I have not encountered any problems. Next, I will discuss the application of the bicycle in thermodynamics with other students.

Student 1: I was looking for optical and electrical applications of bicycles. The design of the bicycle "taillight" uses optical knowledge. Next, I will ask my teacher and discuss with other students.

Appendix 3
Student activity of "Reporting learning outcomes"

Students' Activities	Student-Teacher Activities
The first group reports to the class on what they have learned	Student 1: Our group will report on what we learned firstly. The content I am responsible for is what types of bicycles there are and their structure and function. Bicycles mainly include road bikes, mountain bikes, track bikes, and electric bikes. They all have a structure composed of a body part, movable part and a safety device. As for their function, I will provide a written report. Student 2: I am responsible for the knowledge of bicycles in mechanics. The application of force and motion mainly involves increasing and decreasing friction, pressure, work and mechanical energy, as well as simple machinery. For example, there are uneven patterns on bicycles, tires, handle plastic covers, and so on. The front axle, middle axle and rear axle of the bicycle are all rolled to reduce friction. Secondly, the seat, the tire with a washer on the axle nut, and the load-carrying weight on the tire are all in order to increase the pressed area, thereby reducing its pressure on the body. Student 3: Before riding a bicycle uphill, you should step on it a few times to easily go up and convert kinetic energy into potential energy; when riding a bicycle downhill, the speed of the bicycle will be faster and faster without pedaling, and then potential energy will be converted into kinetic energy. The brake handle and the connecting rod in the bicycle braking system is a force-saving lever. The application of bicycles in thermology is mainly reflected in the deflation of bicycle tires. If you put your hand on the deflation, your hand will feel cold. This is because the gas in the tire expands to do work, which reduces the internal energy and temperature of the gas. Student 4: The application in electricity mainly lies in the electric bicycle. It is equipped with a small power generator that works by providing electricity from a battery and an electric motor that drives the bike and provides electricity for the lights to work. In optics, the rear of the bicycle is equipped with a reflector, which will "reverse" when the light is directed at the tail lamp from any angle.
Students from other groups and the teacher ask questions to any students in the first group	Teacher: Now, other people in the group can ask questions about their reports. Student 5: I want to ask student 3, is the structure of the bicycle not used in Acoustics? Student 3: Yes, when some parts are loose during driving, it will cause vibrations and sound. Secondly, because the bell cover keeps vibrating, the bicycle makes the car ring. Student 6: I would like to ask student 2, as you mentioned, when people ride a bicycle forward, the bicycle still moves forward after stopping pedaling, why? Student 2: The bicycle is inertial. Teacher: The first group of students reported well and organized clearly, but the inductive methods of mechanics and acoustics were not applied properly, so I hope to continue to supplement them perfectly.

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Appendix 4
Pre-post-test Scores of the Experimental and Control Groups

Item	Experimental		Control	
	Pre-test	Post-test	Pre-test	Post-test
1	69	83	60	57
2	61	77	52	59
3	64	77	59	69
4	75	87	52	58
5	61	60	56	48
6	65	81	52	59
7	61	71	58	53
8	85	91	85	84
9	68	78	53	58
10	74	84	73	63
11	54	75	85	84
12	64	85	44	49
13	79	80	67	64
14	51	51	52	60
15	70	76	65	64
16	27	44	71	65
17	71	82	65	73
18	66	72	40	46
19	63	71	67	72
20	64	65	69	78
21	66	74	45	48
22	42	63	44	43
23	56	68	66	67
24	37	49	56	65
25	41	67	53	58
26	58	54	62	66
27	61	65	41	57
28	56	59	34	56
29	56	60	43	45
30	28	39	36	37
31	43	49	66	62
32	62	63	38	60
33	45	57	54	46
34	61	61	51	68
35	54	62	50	53
36	45	57	44	40
37	59	71	29	34
38	29	42	42	52
39	52	56	37	44

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Item	Experimental		Control	
	Pre-test	Post-test	Pre-test	Post-test
40	31	33	38	52
41	52	55	33	30
42	38	45	40	45
43	47	52	31	41
44	36	42	35	35
45	32	62	31	33
46	30	45	31	40
47	43	63	31	29
48	49	89	34	39
49	29	37	23	36
50	30	34	28	33
51	25	46	29	38
52	18	21	33	30
53	38	45	27	33
54	52	70	37	36
55	37	39	23	24
56	34	39	30	36
57	54	65	47	52
58	26	42	39	50
59	51	52		
60	60	67		
61	59	60		

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