Asia Pacific Education Review (2018) 19:401–411
https://doi.org/10.1007/s12564-018-9540-y

Improving learning process in genetics classroom by using metacognitive strategy

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Received: 26 February 2017 / Revised: 8 January 2018 / Accepted: 27 April 2018 / Published online: 10 May 2018

Abstract
Strategies applied in this study consisted of a metacognitive strategy combined with cooperative learning (MSCL) and one without cooperative learning (MS). Both strategies used the self-understanding and evaluation sheet (SUES). The aims of this study were to investigate the effect of MSCL and MS on the quality of the learning process in genetics classroom. High- and low-ability students were also compared with regard to the effect of both strategies on their academic performance. Four learning process variables were examined: metacognitive skills, collaborative skills, genetics knowledge, and academic achievement. A quasi-experimental research design was used to compare the MSCL ($n=30$) and MS ($n=30$) groups in which each group consisted of low ($n=15$)-ability and high ($n=15$)-ability students. Results showed that MSCL group portrayed higher collaborative skills but lower metacognitive skills than MS group. However, both groups had no influences on other variables: genetics knowledge and academic achievements. In addition, high-ability students performed higher metacognitive skills, genetics knowledge, and academic achievements than low-ability students, whereas both of them showed relatively similar collaborative skills. As a suggestion, this study recommends that metacognitive strategy can be done in collaborative designs by using SUES as the authentic assessment.

Keywords Metacognitive strategy · Cooperative learning · Genetics learning

Introduction

Genetics classroom offers extensive knowledge to help students understand scientific and everyday life phenomena. However, most students still face difficulties in learning genetics proven by the presence of misconceptions (Andrews et al. 2012; Smith and Knight 2012; Susantini 2009a; Williams et al. 2012) and low achievement (Dougherty et al. 2011; Shaw et al. 2008). Some previous studies stated that low achievement in genetics classroom occurs due to the inadequate learning environment and poor teaching strategy, of which do not consider students' prior knowledge and interaction during the learning process (Susantini 2009a; Sorgo et al. 2014). Teachers mainly conduct only hands-on activities, laboratory practices, and classical presentations, but leave students with no opportunities to actively restructure and integrate new information into a set of knowledge.

In addition, metacognitive strategy can be used to promote self-regulated learning as an attempt to improve the learning process and to achieve the quality in classroom activities (Sart 2014; Schraw et al. 2006; Seraphin et al. 2012). Metacognition is known as a set of knowledge that includes (a) personal ability awareness (declarative knowledge), (b) general strategies used in different tasks (procedural knowledge), and (c) conditional knowledge ("when" or "why") with a specifically effective strategy used to cope with the knowledge (Pintrich 2002; Schraw 1998). In this present study, metacognition is meant as a learning strategy where students are encouraged to know how to use both procedural and conditional knowledge in

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s12564-018-9540-y) contains supplementary material, which is available to authorized users.

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order to achieve the learning goals. The implementation of metacognitive strategy is in line with the effective science instruction that aims to increase both learning and metacognitive skills, yet leading students to the higher level of science (Schraw et al. 2006). In order to foster the use of metacognitive strategy, teachers need to help students recognize what they have known and what they have learned. In this case, students are expected to seek helps; develop an awareness regarding their own strength and weakness; engage in independent cooperative activities with peers; find learning resources independently; make a research journal as planning, monitoring, and reflecting an ongoing work; and evaluate their problem-solving tasks (Anderson et al. 2003; White et al. 2009).

Indeed, it is very challenging to make teachers teach metacognitive strategy since teachers tend to develop higher-order thinking instructions in the classrooms with high-ability students rather than with those low-ability ones (Raudenbush et al. 1993). This is happening because many teachers believe that training high-order thinking is only suitable and effective for high-ability students, while drilling and other memorization practices are merely appropriate for only those in the lower class (Zohar et al. 2001; Warburton and Torff 2005). Therefore, by referring to the constructivist philosophy of an active involvement in learning and a self-regulated learning initiation among diverse students' abilities, there has been a considerable educational interest about metacognitive strategy implementation combined with cooperative learning (Eldar et al. 2011; Jayapraba and Kanmani 2014; Kramarski and Mevarech 2003; Listiana et al. 2016; Sandi-Urena et al. 2011). Still related to diverse students' ability in a classroom, previous studies reveal that teaching metacognition surely affects the reasoning skills of both high-ability and low-ability students (Zohar and Peled 2008; Zohar and David 2008). The latest study also demonstrates that self-regulated learning has a different effect on academic achievements and metacognitive skills disseminated by students' abilities (DiFrancesca et al. 2016). Planning high-performance goals, which is one of the metacognitive skills components, can be beneficial for low-performing students (Luo et al. 2011). However, from the studies above, it has not been clear if metacognitive strategy with cooperative learning integration would rise positive effects on the learning process in genetics classroom (as a subject area with high demand for high-order thinking). In addition, the classroom benefits of implementing metacognitive strategy combined with cooperative learning with diverse student ability are still questionable. This study addresses a prominent question on the comparison of MSCL and MS toward four possible measurements of metacognitive strategy-cooperative learning (MSCL) learning process in genetics classroom: metacognitive skills, collaborative skills, genetics knowledge, and academic achievements. Moreover, another question occurs to confirm the first question about the students' responses regarding implementation of both the strategies.

This study aims (1) to examine whether metacognitive strategy-cooperative learning (MSCL) and metacognitive strategy (MS) are able to improve a learning process in genetics classroom, and (2) to examine the effect of different students' ability in genetics learning process; and (3) to describe students' responses regarding implementation of both the strategies.

Method

Design

This experimental research used Factorial Design (Fraenkel et al. 2012) in which quantitative data were used to measure the effect of MSCL and MS on metacognitive skills, collaborative skills, genetics knowledge, and academic achievement disseminated by two classes of students' abilities; high and low students' abilities. Besides, the data were also obtained from a questionnaire used to determine students' response. This questionnaire was then assigned to the two treatment groups (MSCL and MS) which had an equal number of students ($n = 30$ for each group). Thus, we had four subgroups in a 2×2 design consisting of the low-ability MSCL subgroup, low-ability MS subgroup, high-ability MSCL subgroup, and high-ability MS subgroup. In order to point out the difference, students in MSCL group received a metacognitive strategy instruction combined with cooperative learning, whereas the other one was given the same strategy with individual learning. In this case, all students were taught by the same teacher in the same amount of time allocation to control the input of metacognitive training across two different groups.

Participants

There were 60 students participating in this study who were in the 12th grade (17–18 years old) of a senior high school in Surabaya, East Java, Indonesia. They originally came from two different classes that had a similar academic and sociocultural background. Moreover, they were categorized into two academic achievements either in low or high students' ability based on their GPA scores in the previous semester. This categorization showed (1) 15 students for each category from the first class, which then subsequently designed to be treated with MSCL; and (2) the same amounts from the second class, which then being treated with MS.

Learning materials and teacher training

Before beginning the study, researchers developed four different sets of learning materials to cover four different topics in genetics topic (1) nature of genes and genetic materials, (2) patterns of genetic inheritance, (3) genetic inheritance in human, and (4) mutation. Each set of learning materials included a student book, a metacognitive log so-called Self-Understanding and Evaluation Sheet (SUES) (Susantini 2009b) and a test book. The development of the learning materials followed the 4-D model of instructional design (defining, designing, developing, and disseminating) (Thiagarajan et al. 1974). In the 'developing' stage, the learning materials were validated by genetics education experts and the first revised draft was tested in a local senior high school. In accordance with the result, the learning materials were revised again and re-tested in another local junior high school. The latest revision was further used in the experimental groups of this study.

In connection with the current study, the teacher was exposed to one-week pedagogical training, which focused on differentiated instructions between MSCL and MS. Authors decided to deliver the treatment with the help of the same teacher to ensure the equal input of information and identical delivery of metacognitive training. Consequently, it was not possible to blind the teacher to the different treatments between MSCL and MS groups. Teacher's training included theoretical background and the rationale of metacognitive strategy and cooperative learning followed by practical applications to incorporate various study strategies in the biology classroom. Study strategies included note-taking, underlining, summarizing, outlining, mapping, and mnemonics and its implementation in core topics of genetics. Incorporation of study strategies into teacher's training was used to introduce the teacher to the explicit instruction that enables the students to come up with an effective study plan to solve questions. The teacher was also familiar with the detailed lesson plans of MSCL and MS along with learning materials developed by the authors.

Metacognitive strategy

In this present research, the metacognitive strategy was introduced in the classroom based on the general techniques of improving thinking skills proposed by Hartman and Sternberg (1993). These included four stages namely *differentiating, refining, elaborating*, and *interrelating*. Figure 1 shows essential students' activities at each stage and its explanation that is used as theoretical framework in this study.

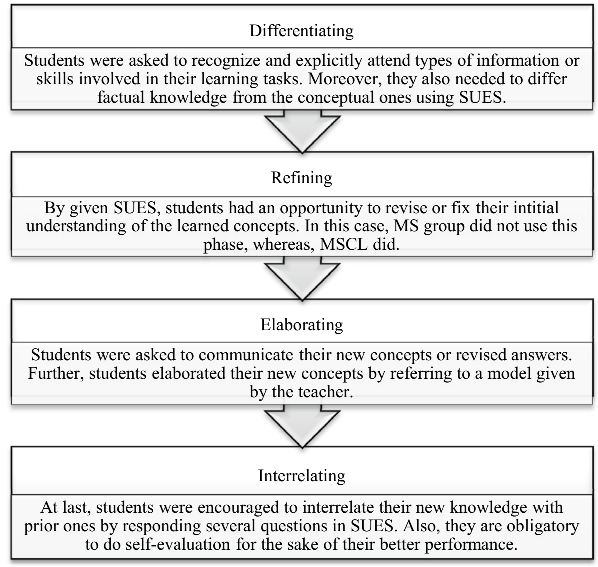

Fig. 1 Underlying theoretical framework of metacognitive strategy

Classroom procedures

Each student from two treatment groups participated in 24 sessions (5 months) of learning activities that cover all topics about genetics: six sessions about the nature of genes and genetic materials; six sessions about patterns of genetic inheritance; four sessions about genetic inheritance in human; four sessions about mutation; and four sessions for end-of-topic test. Each session of both treatment groups lasted for approximately 90 min with six general phases (Susantini 2009b) namely (1) clarifying learning goals and explore pre-existing knowledge; (2) organizing students' learning process; (3) monitoring students' conceptual change; (4) presenting important concepts; (5) checking students' understanding and providing feedback; and (6) encouraging self-monitoring and self-evaluation. Table 1 shows the essential activities in the six phases.

Metacognitive strategy combined with cooperative learning (MSCL)

A distinct feature of the treatment given to the MSCL group is a free-ranging discussion with four required activities namely *questioning, clarifying, summarizing*, and *predicting* (Brown and Palincsar 1986). This feature has appeared in the second phase of classroom session conducted by the teacher (i.e., organizing students' learning process). As the teacher was assigned to break the classical class into small groups, students changed their position into group seatwork and promoted a group leader who had a responsibility to lead the discussion. However, later, each member of the groups took a turn to be a group leader. The group leader began the

Table 1 Teacher and student activities in six phases

Phases	Activities
Clarifying learning goals and exploring initial knowledge	Teacher explained specific learning goals, motivated students in a brainstorming session, distributed SUES, and guided students in responding SUES
Organizing students' learning process	Teacher divided a class into groups and asked each group to do collaborative works among members in drawing their initial knowledge
Monitoring students' conceptual change	Teacher ungrouped the class and asked them to differentiate between their initial and new knowledge classically
Presenting important concepts	Teacher explained the important concept drawn in student's book and guided students to use diverse learning strategy
Checking students' understanding and providing feedback	Teacher discussed students' works in SUES classically to check whether there was still a misconception
Encouraging self-monitoring and self-evaluation	Students were asked to self-assess their works based on an agreed score range. Then, students, with teacher's guidance, concluded the correct concept

discussion by reading the question in the SUES and asked each member of the group to try to answer the question. Each member is given time to read their student book or just talk about what they had already known. Then, each group generated an answer together and clarified whether they already reached the conceptual understanding or question asked. Whenever a disagreement occurred, the group leader was asked to read the question again and clarified the answer until the group reached the consensus. An answer that was extraneous to the consensus results was not allowed to be written on the second page of SUES. The group could monitor their progress in the SUES completion by summarizing what they agreed and disagreed. Any question in the SUES which was really hard to answer can be predicted together by the members of the group and written down in the SUES as a temporary consensus.

Metacognitive strategy (MS)

On the second phase of the classroom session, students were directed to learn individually without discussing with other classmates to finish the second page of SUES. While students worked, the teacher provided guidance to those who needed it. This group served as control group.

Data collection and analysis

Self-understanding and evaluation sheet (SUES)

Self-Understanding and Evaluation Sheet (SUES), a developed student activity sheet called 'Flex Your Brain' (Biggs et al. 1997), consisted of two pages of a worksheet which were given to the students at different times. The first page of SUES was given to the students *before* instruction and intended to be used to explore students' prior knowledge. This first page of SUES consisted of sets of questions (can be multiple choices or short-answer question or both) related to the topics studied that should be answered by the students in a given time. Students were told that they should answer the questions on their own (without discussion with their classmates or cheating) and the questions were only used to identify their pre-conceptions before the class started. At the end of this first page of SUES, students were asked to give a scale representing how much they believe that they successfully answer the question (self-efficacy). The scale ranged from *absolutely sure, somewhat sure*, and *absolutely unsure* of each number of the answered question given. Later, together with the help of teacher's instruction, the last section of the first page of SUES asks the students to form a group (in MSCL group) or just remain in individualized setting (in MS group) and the research questions further use of the provided student book. Upon the instruction, teacher distributed the second page of SUES which was composed of identical questions to the first page. The second page of SUES provided students with a chance to revise their initial concepts or knowledge based on what they have learned (self-monitoring). Apart from that, the second page of SUES was also intended to help students to consider their own thinking and thinking from their peers (in MSCL group). At the end of the section of the second page of SUES, students were asked to record "Do I think differently?" for each number of question. Furthermore, students were asked to give a self-administered score (self-evaluation) toward their answers for the questions given in SUES. Henceforth, SUES functions as one form of metacognitive training that assists the students to examine their way of thinking through the exploration of their prior knowledge, the new or acquired conclusions and awareness, and the encouragement of self-reviewing of how they arrive at the new conclusion. SUES later also functioned as a measurement of students' metacognitive skills, collaborative skills, and genetics knowledge.

As discussed by Pifarre and Cobos (2010) and Schraw (2009), metacognitive skills refer to students' ability to do the self-monitoring and self-evaluation by comparing their prior knowledge (pre-conception) and the classroom-acquired knowledge (new conception), and by assessing their own concept accuracy. Collaborative skill covers group's ability in completing given tasks. Genetics knowledge variable is defined as the acquired genetics concept after the students learn with metacognitive strategy, while academic achievements are tightly linked to the score of test given at the end of learning sessions. Metacognitive skills, collaborative skills, and genetics knowledge were assessed through SUES. Each of these variables was scored with 0–100 range. Academic achievement was measured through a test given at the end of each topic. The test consists of multiple choices questions and essays that have been previously examined for its validity and reliability by some experts.

MANCOVA was used to analyze the measured variables from each topic that was studied by the students. Treatment groups (MSCL and MS) and students' ability (high-ability students and low-ability students) acted as the independent variable, and a measured parameter of the learning process (metacognitive skills, collaborative skills, genetics knowledge, and academic achievements) acted as the dependent variable. Prior knowledge was accounted as a covariate. Before carrying out MANCOVA, the prerequisites were checked with Levene's test for equal variances. If the p value > 0.05 the data will be considered as homoscedastic or have equal variance. Data with unequal variance were analyzed with General Linear Model (GLM). Students' responses were assessed through a questionnaire that consisted of 16 yes or no items. These responses were analyzed descriptively.

Results

Comparison of MSCL and MS by metacognitive skills

The average score for all variables was summarized in Table 2. In metacognitive skills, Levene's test for genetics topics revealed $F = 1.920$ and significance degree of 0.137 (nature of genes and genetic materials), $F = 3.459$ and significance degree of 0.022 (patterns of genetic inheritance), $F = 10.403$ and significance degree of 0.000 (genetic inheritance in human), and $F = 10.926$ and significance degree of 0.00 (mutation). The significant effect of learning strategy (Table 4) and student's ability (Table 5) on four observed variables (metacognitive skills, collaborative skills, genetics knowledge, and academic achievements) was then computed using multiple ANCOVA. Most topics of genetics showed that the implementation of MSCL and MS has a highly significant effect on the development of metacognitive skills ($p < 0.01$). The student's ability also showed the highly significant effect on the development of metacognitive skills ($p < 0.01$) in which high-ability students have higher metacognitive skills than low-ability students. However, surprisingly, the result implies that the metacognitive skills of MSCL groups were lower than the metacognitive skills of MS groups (Table 2).

Table 2 Effect of metacognitive strategy-cooperative learning (MSCL) and metacognitive strategy (MS) on four variables of learning process in genetics classroom comprising high-ability (HA) and low-ability (LA) students

Topics	Groups	Students	Average score (SD)			
			Metacognitive skills	Collaborative skills	Genetics knowledge	Academic achievements
Nature of genes and genetic materials	MSCL	HA	76.33 (11.01)	66.67 (26.16)	85.40 (8.55)	86.33 (2.97)
		LA	60.67 (19.62)	65.00 (26.39)	74.80 (14.36)	65.07 (2.09)
	MS	HA	90.67 (10.07)	50.00 (23.15)	80.27 (10.33)	85.40 (4.29)
		LA	67.67 (19.45)	48.33 (24.03)	73.60 (12.21)	62.47 (8.41)
Patterns of genetic inheritance	MSCL	HA	87.80 (11.31)	70.00 (21.55)	86.00 (9.19)	73.60 (8.01)
		LA	62.33 (22.19)	70.00 (21.55)	77.60 (8.68)	45.60 (14.27)
	MS	HA	93.67 (8.03)	55.00 (25.35)	83.60 (5.51)	72.13 (12.68)
		LA	75.07 (20.29)	55.00 (25.35)	73.20 (12.55)	39.33 (17.88)
Genetic inheritance in human	MSCL	HA	90.40 (11.02)	93.33 (14.84)	96.73 (3.91)	91.00 (9.93)
		LA	51.60 (29.29)	86.67 (20.85)	90.20 (5.77)	67.80 (18.74)
	MS	HA	94.27 (8.74)	51.67 (25.82)	96.47 (4.10)	89.33 (10.39)
		LA	90.53 (10.90)	45.00 (23.53)	87.07 (8.65)	65.27 (20.75)
Mutation	MSCL	HA	86.87 (14.22)	86.67 (12.91)	86.67 (4.19)	78.47 (7.69)
		LA	68.93 (27.59)	85.00 (12.68)	85.13 (4.98)	58.67 (11.78)
	MS	HA	96.73 (6.58)	60.00 (24.64)	86.27 (3.94)	72.20 (11.21)
		LA	81.53 (24.30)	53.33 (18.58)	80.67 (6.87)	51.67 (13.52)

In collaborative skills, Levene's test revealed $F = 0.498$ and significance degree of 0.685 (nature of genes and genetic materials), $F = 0.391$ and significance degree of 0.760 (patterns of genetic inheritance), $F = 2.119$ and significance degree of 0.108 (genetic inheritance in human), and $F = 2.224$ and significance degree of 0.095 (mutation), indicating homogenous variance and continuation to multiple ANCOVA. All of the genetics topics showed that the implementation of MSCL and MS significantly affects the development of students' collaborative skills ($p < 0.01$). The MSCL groups apparently showed better collaborative skills than MS groups (Table 2). It was also shown that student's ability difference does not affect students' collaborative skills (Table 5).

Levene's test of knowledge variable resulted in $F = 0.506$ and significance degree of 0.680 (nature of genes and genetic materials), $F = 2.522$ and significance degree of 0.067 (patterns of genetic inheritance), $F = 2.594$ and significance

Table 3 Analysis of variance for metacognitive skills on the topic of nature of genes and genetic materials

Source	DF	Seg SS	Adj SS	Adj MS	*F*	*p*
Prior knowledge	1	830.9	271.4	271.4	1.10	0.299
Learning method	1	1350.5	1855.3	1855.3	7.50	0.008**
Student talent	1	5396.1	5484.9	5484.9	22.18	0.000**
Learning method × student talent	1	229.7	229.7	229.7	0.93	
Error	55	13602.2	13602.2	247.3		0.339
Total	59	21409.4				

Term	Coef	SE Coef	T	*p*
Constant	77.587	4.063	19.09	0.000
Prior knowledge	− 0.1506	0.1438	− 1.05	0.2999

$S = 15.7262$, $R^2 = 36.478$, $R^2(\text{adj}) = 31.85\%$

**$p < 0.01$, highly significant

Table 4 Significance effect of learning strategy (MSCL and MS) on observed variables

Topics	*p* value of variables			
	Metacognitive skills	Collaborative skills	Genetics knowledge	Academic achievements
Nature of genes and genetic materials	0.008**	0.008**	0.224	0.695
Patterns of genetic inheritance	0.031*	0.014**	0.137	0.304
Genetic inheritance in human	0.000**	0.000**	0.213	0.838
Mutation	0.037**	0.000**	0.157	0.128

**$p < 0.01$, highly significant; *$p < 0.05$, significant

Table 5 Significance effect of student's ability (high and low ability) on observed variables

Topics	*p* value of variables			
	Metacognitive skills	Collaborative skills	Genetics knowledge	Academic achievements
Nature of genes and genetic materials	0.000**	0.880	0.030*	0.000**
Patterns of genetic inheritance	0.000**	0.565	0.007**	0.000**
Genetic inheritance in human	0.000**	0.269	0.000**	0.000**
Mutation	0.007**	0.884	0.022*	0.000**

**$p < 0.01$, highly significant; *$p < 0.05$, significant degree of 0.062 (genetic inheritance in human), and $F=1.965$ and significance degree of 0.130 (mutation), indicating homogenous variance across all topics of genetics. The significance of learning strategy and student's ability effect on students' genetics knowledge was then tested with multiple ANCOVA. Table 4 shows that there was no significant effect of the implementation of MSCL and MS on the development of genetics knowledge. However, students' ability showed a significant effect on this variable ($p<0.01$ in patterns of genetic inheritance and genetic inheritance in human; $p<0.05$ in nature of genes and genetic materials as well as mutation). High-ability students showed higher acquired genetics knowledge than low-ability students, either in MSCL or MS groups (Table 2).

Table 3 shows the result of ANCOVA in examining the effect of MSCLS and MS upon four variables of metacognitive skills on the topic of nature of genes and genetics materials. A similar procedure is applied to examine the other three variables of metacognitive skills under other three different topics namely patterns of genetic inheritance, genetic inheritance in human, and mutation. Then, the results of significance scores are drawn as follows (see Tables 4, 5).

As for academic achievements, Levene's test for genetics topics resulted in $F=5.902$ and significance degree of 0.001 (nature of genes and genetic materials), $F=1.860$ and significance degree of 0.147 (patterns of genetic inheritance), $F=2.714$ and significance degree of 0.053 (genetic inheritance in human), and $F=0.773$ and significance degree of 0.514 (mutation). Afterwards, the significance effect of learning strategy and student's ability on academic achievements was determined by multiple ANCOVA. The implementation of MSCL and MS showed no effect on students' academic achievements, with smaller standard deviation in MSCL group (Table 4). Even so, student's ability had a highly considerable effect on this variable across all topics ($p<0.01$) (Table 5). It can be clearly seen that high-ability students showed better academic achievements than low-ability students (Table 1). Multiple ANCOVA also showed that the interaction between learning strategy and student's ability does not affect metacognitive skills, collaborative skills, genetics knowledge, and academic achievements. The positive response from MSCL and MS groups about metacognitive strategy can be seen in Table 6.

Students' responses to MSCL and MS implementation

See Table 6.

Discussion

Metacognition has been viewed not only as a learning strategy and self-knowledge, but also as a facet of skills consisting planning, information management, inference, recognizing assumptions, interpretation, deduction, monitoring, and evaluation (Magno 2010). In order to improve students' learning process, this study addressed how metacognitive strategy combined cooperative learning in genetics classroom influences metacognitive skills. The implementation of MSCL and MS in genetics classroom considerably affected metacognitive skills in which MS group demonstrated higher metacognitive skills than MSCL group. It can also be observed that student's ability also shows the

Table 6 Students' responses about metacognitive strategy using self-understanding and evaluation sheet (SUES) within MSCL and MS

Statements	MSCL group (%)	MS group (%)
1. I understand the concept easier by reading the student's book	97.50	88.37
2. The language used in the student's book is not confusing	97.50	76.74
3. I would like to learn other topics with this kind of student's book	97.50	90.70
4. I am more enthusiast to learn genetics with self-understanding and evaluation sheet (SUES)	100.00	95.35
5. I learn the topics before I attend the class because I know I will need to do the SUES first	57.50	46.51
6. I would have never cheated to complete my SUES	75.00	58.14
7. I am not embarrassed to confess that my answers in SUES are incorrect	92.50	96.67
8. I think I can be more honest when I learn with SUES	97.50	93.02
9. Self-understanding and evaluation sheet (SUES) enable me to monitor and manage my learning process	97.50	97.67
10. The classroom is way more active and fun with SUES	80.00	55.81
11. I can understand important concepts with SUES	95.00	95.35
12. I am more motivated to learn in cooperative groups	87.50	86.05
13. I am more motivated when I learn individually	12.50	13.93
14. I prefer to explain to my friends rather than giving him/her direct/final answer	85.00	83.72
15. Self-understanding and evaluation sheet (SUES) helps me to appreciate different opinion	95.00	90.70
16. I am more enthusiast to learn with my groups if there is reward for the best group	90.00	90.70

highly significant effect on the development of metacognitive skills. High-ability students gained higher metacognitive skills than low-ability students in both MSCL group and MS group. This result is consistent with a study from DiFrancesca et al. (2016) who reported that high-ability students have higher metacognitive monitoring skills compared to low-ability students. Moreover, when high-ability students received metacognitive training, they also showed increased tendency to use metacognitive skills in the long run (Sontag and Stoeger 2015). Thus, we may ask why MS group outperformed MSCL group in metacognitive skills when both groups had highly skilled high-ability students. Perhaps, high-ability students in MSCL group were exploited to work collaboratively rather than focusing on developing their own thinking skills. Cooperative setting requires high-ability students to assist and to offer an explanation to other students who may have a lower grade (Shachar 2003; Jolliffe 2007). Compared to high-ability students in MS group who could perform metacognitive skills individually, aforementioned responsibility may reduce the opportunity for high-ability students in MSCL group to develop their own metacognitive skills. Furthermore, metacognitive teaching conducted by Zohar and Peled (2008) revealed that low-ability students require a longer period (3 months longer) than high-ability students to reach their top score in reasoning skills. A more recent study from Pifarre and Cobos (2010) also proved that 12-month collaborative learning process successfully promotes metacognitive skills, including planning, keeping clarity, and monitoring. We eventually suggest that long-term MSCL implementation in genetics classroom may develop metacognitive skills in MSCL group as good as observed in MS group.

Both MSCL and MS significantly affect students' collaborative skills. The result of this study is consistent with Kramarski and Mevarech (2003) who stated that metacognitive training, combined with cooperative learning, provides a natural setting for students to discuss tasks together. In this present study, MSCL group showed higher developed collaborative skills than MS group. Although there were independent cooperative activities with peers in MS classroom, cooperative learning setting in MSCL group offered more stages that require students to work and to solve problems together with their groups. Consequently, students have the responsibility to work collaboratively, resulting in positive social interdependence, which highly improves teamwork skills to learn effectively as study teams from time to time (Johnson and Johnson 2009). We can also observe that there is no large gap of collaborative skills in high-ability students and low-ability students, either from MSCL or MS groups. Cooperative learning encourages high-ability and low-ability students to work together to complete their academic tasks (Shachar 2003). Hence, students with low, intermediate, or high ability gain positive advantages from their collaboration in learning. Students from MSCL and MS groups also responded that they prefer to learn together rather than learning alone. By learning in small groups with SUES, MSCL students also responded that they develop higher awareness to accept different opinions as well as develop more enthusiasm in learning compared to MS group. This result is consistent with previous studies, reporting that cooperative learning builds less negative attitudes toward conflict and more peer acceptance (Johnson and Johnson 2002; Tsay and Brady 2010). Zakaria et al. (2010) also reported that cooperative learning emphasizes social interaction among groups of students in particular and among classmates in general. As one of the students asserted, "Learning with SUES is fun because it increases solidarity among my classmates in achieving good grades together." We hereby suggest that the nature of self-assessment and peer assessment of SUES potentially increases social acceptance and engagement among students (Hughes et al. 2006).

Interestingly, no significant effect was found on genetics knowledge and academic achievements resulting from the implementation of MSCL and MS. In comparison with the strategy that has been used, both knowledge and student's ability were merely affected by student's ability. As predicted, high-ability students acquired higher genetics knowledge and academic achievements than low-ability students. Thus, it was possible that metacognitive training applied to both groups affected students' genetics knowledge and academic achievements without any influence from the cooperative learning environment. In other words, genetics knowledge and academic achievements still can be developed in metacognitive instructions without any consent of the classroom's settings, either cooperative learning environment like MSCL group or individual learning environment like MS group. To test out this prediction, there should be a group of students treated with cooperative learning without metacognitive instructions in a future study. Despite this possible research gap, there has been a number of studies that also prove that cooperative learning does not outperform individualized learning in improving academic outcomes (Kramarski and Mevarech 2003; Johnson and Johnson 2009). Kirschner et al. (2009a) argued that cooperative learning is more effective and efficient to be used than individual learning as higher-order thinking skills or task complexity increases. It was also confirmed that group learning is better than individual learning to accomplish complex cognitive task if the complex learning tasks could be shared among group members as transfer tasks (Kirschner et al. 2009b). Perhaps, metacognitive instruction, with a high load of cognitive complexity and task with transfer structure that requires the combination of information in order to solve problems, would obtain different results when it is used to compare the effect of MSCL and MS on acquired genetics knowledge and academic outcomes.

In addition, as can be seen in Table 2, the standard deviation of academic achievements in MSCL group was lower than MS group, indicating that students who learned with MSCL showed more equally distributed academic score compared to MS group. For instance, MSCL group obtained academic achievement ranging from 62 to 91 (out of 100) in nature of genes and genetic material topic, whereas MS group showed highly variable academic score, ranging from 43 to 92 (data not shown). Taking this result into consideration, even though both of MSCL and MS do not statistically affect academic score and genetics knowledge, it is preferable to apply MSCL unless we want to solely strengthen metacognitive skills. Implementing MSCL in genetics classroom is way more promising than MS alone because teachers would not only be able to develop students' higher-order thinking skills to master abstract concepts in genetics, but also to improve students' comprehension in genetics knowledge and low-ability students' academic achievements. This is consistent with research from Koles, et al. (2010), stating that cooperative learning provides larger learning benefits in terms of student's ability improvement for low-ability students compared to high-ability students. One student wrote on the questionnaire comments: "I like to learn with this method [MSCL] because I can recognize my incorrect answers and practice many types of exercise in genetics with my friends. I think I can get a better score and be more enthusiastic in learning with this method."

As for the detailed students' response from Table 6, there is an interesting finding of the use of SUES. Students in MSCL and MS group showed relatively similar positive response that they could build more honesty and enthusiasm by learning with SUES. However, as they were asked about the way they would complete or answer questions in SUES, MS group showed more tendencies to cheat compared to MSCL group. Perhaps, cooperative learning environment provides more benefits in building character education toward metacognitive strategy implementation. This is probably due to peer interaction and shared responsibility within group activity offered by cooperative learning (Rokhman et al. 2014). Apart from this result, the teacher can take advantages by using SUES as a part of an authentic assessment in metacognitive training.

Educational implications and future research

Many students have no way of knowing how to focus on understanding science concepts and how to develop problem-solving skills if they have never been explicitly taught learning strategies through higher-order thinking training (Cook et al. 2013). As asserted in the students' response, when the teacher uses MSCL and MS, students experience new effective behaviors to learn genetics and expect to continue using metacognitive strategy and SUES in other subject areas. This strongly suggests schools and teachers implement metacognitive strategy in order to improve the quality of learning process. In addition, as a prominent theoretical contribution, this present study claimed that metacognitive strategy was not only applicable to the individual design, but also can be applied collaboratively. We also offer the following recommendations for educators:

(1) Promoting metacognitive strategy may need carefully designed scaffolding in which teacher assists students to do metacognitive tasks at early sessions, and then increasingly allows them to take charge of their own learning.
(2) To monitor one's own learning progress in terms of self-assessment, teacher can set up general rules to score SUES, asking students to assess their answers by themselves, or simply asking students to exchange answers and assess their friends' answers.
(3) Students are required to be motivated and to focus on their learning progress by applying learning strategy; not to their initial failure or the low score acquired from conducting SUES at the first time.
(4) To simplify the use of SUES as an authentic assessment, the teacher can encourage students to divide their notebook (or logbook/journal) into two parts: upper part to write their prior knowledge before learning and lower part to write their new knowledge or discussion result from classroom interaction.

In future studies, it will be invaluable to extend the MSCL treatment to determine whether metacognitive skills can be improved as high as MS group with a longer period of metacognitive training. We also recommend future researchers to use one more group with cooperative learning treatment (without metacognitive strategy) to check the significance of cooperative learning's influence on promoting students' acquired knowledge and academic achievements. It can be also suggested to modify the learning task in MSCL group as transfer task if teachers want to use this approach to deliver high load cognitive task.

Conclusion

This study pointed that MSCL group gained higher collaborative skills but lower metacognitive skills than MS group. In this case, it is suggested that teachers apply MSCL if the learning goal is set to improve students' collaborative skills. Otherwise, if the learning goal is set to improve metacognitive skills or other higher-order thinking skills, teachers are encouraged to implement MS in the classroom. This study also recommends the use of MSCL to increase students' academic achievements because MSCL promotes more equally distributed academic outcomes in low achievers rather than MS. Concerning this result, implementing MSCL in other subject areas to improve the quality of learning process can be promising.

Another important finding from this study revealed that student's ability affects metacognitive skills, genetics knowledge, and academic achievements, but no proven effect is found on collaborative skills. In detail, high-ability students gained higher metacognitive skills, genetics knowledge, and academic achievements than low-ability students, whereas both groups showed relatively similar collaborative skills score. Hence, it is strongly suggested that teachers organize students into groups with mixed members of high-ability and low-ability students to foster MS implementation in the classroom. We also found that MSCL is fruitful to build character education by developing honesty, team working, self-efficacy, self-expectancy, reflection, and acceptance to multiple viewpoints as students work together in completing self-understanding and evaluation sheet (SUES). The teacher can also get benefit from SUES because students perceive that conceptual understanding and classroom activities become more active and fun by using SUES. We suggest that teachers use SUES as a part of the authentic assessment in MSCL or MS implementation as well as to modify its cost-effective application using notebook or journal to monitor students' learning progress.

Acknowledgements We also gratefully acknowledged Dra. Ika Mustikawati, M.Pd. and students of Senior High School 6 Surabaya for their help in implementing the metacognitive strategy described in this article.

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