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Agent Based Modeling and Simulation of Meta Game of Learning with Two Levels of Learning

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Abstract

Learning refers to concerted activity that increases the capacity and willingness of individuals or groups to acquire and productively apply new knowledge and skills, to grow and mature and to adapt successfully to changes and challenges. Learning is a process of invention and repair from mistake. Everyone can become a learner and learn from the other. Learning is interactive, that is interaction between agents in system, especially in formal education. In the previous research, the interaction is modeled by Meta Game of Learning, which appears after iterated prisoner's dilemma. Learning certainly includes academic studies and occupational training through high school and beyond. But it also encompasses the physical, cognitive, emotional and social development. Meta game of Learning is a model that involves the interaction between two agents, *i.e.*, teacher and student in the classroom. In this model, teacher has two choices, "give a hard or easy question"; and student has also two choices, "give the respond with a right or wrong answer". These terms correspond loosely to Cooperate and Defect. In the Meta game of Learning, when hard question are answered correctly, the learner is learning, *i.e.*, the result of mutual cooperation on the part of both agents. Interaction that happens at a particular formal education system has the character of dynamic. This paper studies about Meta game of learning; in which of the teacher can pose to the student either hard or easy question and student can respond with either try learning or not try. *First*, the interaction is modeled by Meta game of learning. *Then*, it proposes a learning model which involves two interactions, *i.e.*, an interaction between teacher and students; and the other one is among students (*i.e.*, team based learning) by using an agent based simulation approach. The response a student chooses depends on a number of internal attributes there is ability that determines the relative ease with which the student learns new concept; motivation that determines, in part, the likelihood of cooperation; in general, a high value for motivation is commensurate with cooperation and emotion that represents the student's emotional state, or relative happiness, contentment, etc. *Finally*, it answers

the following questions: Is team discussion learning better than individually test learning?

Keyword: Meta game of Learning, Learning, Agent based

1. Introduction

Based on the assumption that learning is fundamentally interactive, we study the types of interaction that occur in a traditional educational setting. The interaction between teachers and students is modeled by a *Meta Game of Learning* [2], which is fashioned after the *iterated prisoner's dilemma* (IPD). In the model, the interaction between teacher and student is repeated as two agents in a synchronized version of the IPD. Each player can make one of two moves at each of iteration. The teacher goes first and presents to the student either a hard or an easy question. The student responds with either a right or wrong answer [2]. The term of Meta game is applied to refer to the overarching system of interactions between multiple agents of each type over much iteration.

Figure 1 illustrates the Meta game of learning using a matrix of possible question answer pairs, labeling the type of experiences associated with the pair in each case. It posits that within the four simple experiences shown in Figure 1. The response a student chooses depends on a number of internal attributes with definite values.

- Ability (A) – determines the relative ease with which the student learns a new concept.
- Motivation (M) – determines, in part, the likelihood of cooperation; in general, a high level of motivation is commensurate with cooperation (*i.e.*, responding with the right answer when the student is trying) and converse for defection
- Emotion – represents the student's emotional state or relative happiness, contentment, etc., as a variable related to both ability and motivation.

<i>Teacher</i>	<i>Student Response</i>	
	Right Cooperate	Wrong Defect
Hard Cooperate	<i>Learning</i>	<i>Frustration</i>
Easy Defect	<i>Verification</i>	<i>Boredom</i>

Figure1: The Meta Game of Learning (MGL) [2]

In this paper, we expand the Meta game of learning by focusing on modeling complexities in the student's behavior. In our research, we will propose a learning model with two levels by using agent based simulation model approach. At the first level, we modeled the interactions between teachers and students and the manner in which these agent are rewarded as a Meta Game of Learning, and at the second level, we modeled the interactions between students and the other students in the same class.

Our long-term direction with this work is to explore decision-making in pedagogical agents who choose between presenting students with hard and easy questions at various stages throughout a series of iterated interactions, with the overarching goal of the student learning in their group (team based learning). The goal of our research is to answer the following question: Is team test discussion better than individually test learning?

Although in theory these attributes may be considered continuous (possibly vector-valued) functions over team, we attempt to capture their essential behavior with models employing discrete (binary) values that change through the course of interaction according to simple rules.

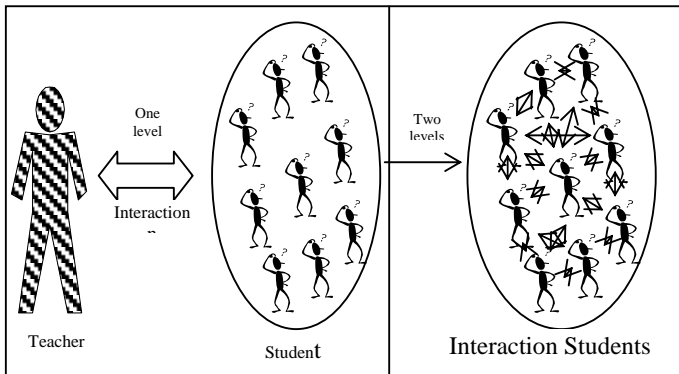


Figure 2: Two Levels of Learning

2. Rule of Response

In this research, we use Meta Game of Learning that considers the teacher and student as two

agents in a synchronized version of the IPD. Each player can make one of two moves at each of iteration. The teacher goes first and presents to the student either a hard or an easy question. The student responds with either to try learning or not try. In this research, we make foundational rule for motivation and emotion can be stated very simply as same as Sklar. We define our rules in the first and second levels of learning model. At the first level, a student's motivation level (i.e., desire to cooperate or defect) may change depending both on the course of interaction with the teacher, and on changes in the student's emotional state. The foundational rule involves only the two variables of the interaction [2], i.e., the choice of each agent to cooperate or defect.

In this research, we state of the rule at level one as follows: a reward for a given choice encourages making the same choice next time; punishment for a given choice encourages making the opposite choice next time. This rule is expressed in terms of the motivation variable, using the payoff matrix shown in Figure 3. For example, if the teacher defects and student cooperate is making the student's motivation to cooperate decreases, making the student less likely to cooperate the next time.

<i>Teacher</i>	<i>Student</i>	
	Try to Learn Cooperate	Not Try to Learn Defect
Give Hard Question Cooperate	<i>M+</i>	<i>M-</i>
Give Easy Question Defect	<i>M-</i>	<i>M+</i>

Figure 3: Changes in Student's Motivation

The positive indicator (+) means that the value of the attribute increases;

Negative (-) indicates that the attribute decreases

Since the primary focus of this Meta game is on the student's learning, we suppose that an agent's emotional state is affected mainly by the student's actions. If we extend the example illustrating the motivation rule, our supposition suggests that when a student cooperates, both student and teacher tend to feel encouraged and experience a positive change in their emotional state. Conversely, when a student defects (for instance, because the student's motivation level has dropped, or the student becomes tired), both student and teacher may feel discouraged and experience negative changes, although not necessarily to the same degree. The rule is expressed schematically in Figure 4.

<i>Teacher</i>	<i>Student</i>	
	Try to Learn <i>Cooperate</i>	Not Try to Learn <i>Defect</i>
Give Hard Question <i>Cooperate</i>	<i>E+</i>	<i>E-</i>
Give Easy Question <i>Defect</i>	<i>E+</i>	<i>E-</i>

Figure 4: Changes in Student's Emotion
The positive indicator (+) means that the value of the attribute increases;
Negative (-) indicates that the attribute decreases

The rule of change in student's motivation and emotion at level one can be expressed schematically in Figure 5.

<i>Teacher</i>	<i>Student</i>	
	Try to Learn <i>Cooperate</i>	Not Try to Learn <i>Defect</i>
Give Hard Question <i>Cooperate</i>	<i>M+, E+</i>	<i>M-, E-</i>
Give Easy Question <i>Defect</i>	<i>M-, E+</i>	<i>M+, E-</i>

Figure 5: Changes in Student's Motivation (M) and Emotion (E)
The positive indicator (+) means that the value of the attribute increases;
Negative (-) indicates that the attribute decreases

Note that the Student's emotion E will invariably go up if she answers correctly, or down if she answers incorrectly; the change in emotion depends only on the Student's action. Conversely, the change in motivation depends only on the Teacher's choice in the current round. These changes may be loosely interpreted as corresponding to real situations, although we stress here that no fixed interpretation is necessary (or even desirable), as long as there is some consistent interpretation within the MGL framework.

The effect of these rules may be seen as follows:

1. If the Teacher and Student both cooperate, for instance, a teacher presents a challenging question that a student correctly answers, affirming the student's effort, then the Student's motivation M and emotion E both increase (or, possibly, remain high) and the Student makes progress, i.e., P increases.

2. If the Teacher defects while the Student cooperates, although the Student's emotion E goes up, she did, after all, answer the question correctly, the Student's motivation M goes down (or remains low), since the easy question required little effort. The Student becomes less likely to cooperate the next time, although she still made progress in the current round.
3. If the Teacher cooperates with a challenging question, while the Student defects, the Student's motivation will go down, together with emotion a student may still learn from incorrectly answered questions, but if the questions are consistently too difficult, failure is certain, and there is little incentive to apply much effort to them. This interpretation of defection for the Student is less intuitive.
4. If both Student and Teacher defect, then the Student's emotion still decreases, but her motivation increases, failing to give a right answer that one was capable of giving has no learning value at all, and a student in that situation tends to feel renewed incentive to work.

At the second level, we modeled the interactions between students and the other student in the same class. In this research, we proposed information as a factor that influenced a progress of learning at two levels. We make the simple rules for the changes in student's information. The rule is expressed schematically in Figure 6.

<i>Student n</i>	<i>Student m</i>	
	Try to Learn <i>Cooperate</i>	Not Try to Learn <i>Defect</i>
Try to Learn <i>Cooperate</i>	<i>I+</i>	<i>I+</i>
Not Try to Learn <i>Defect</i>	<i>I-</i>	<i>I-</i>

Figure 6: Changes in student's information
The positive indicator (+) means that the value of the attribute increases;
Negative (-) indicates that the attribute decreases

The rule of change in student's motivation, emotion and information can be expressed schematically in Figure 7.

<i>Student n</i>	<i>Student m</i>	
	Try to Learn Cooperate	Not Try to Learn Defect
Try to Learn Cooperate	$M+, E+, I+$	$M+, E-, I+$
Not Try to Learn Defect	$M-, E+, I-$	$M+, E-, I-$

Figure 7: Changes in Student's Motivation (M), Emotion (E) and Information (I)

The positive indicator (+) means that the value of the attribute increases;

Negative (-) indicates that the attribute decreases

The effect of these rules may be seen as follows:

1. If student n and student m both cooperate, then the Student's motivation M and emotion E both increase (or, possibly, remain high), and also information I increase, because they try to learn and there are knowledge sharing.
2. If student n cooperate while student m defect, then motivation of student m increase, because they interact with student who try to learn, her emotion decrease, however an obtained information increase, because student m contact with student n who cooperate.
3. If student n defect, while student m cooperate, then student's motivation decrease because student m interact with student who don't try to learn, her emotion increase, but information that obtained by student m will decrease, because he doesn't get new information.
4. If student n and student m both defect, student's motivation decreases, also her emotion and information, because they don't get new information.

3. Model and Simulation

In this model, one pedagogical agent (the teacher) interacts simultaneously with many (n) Student agents at the first level. The teacher presents a finite series of related concepts from the knowledge domain in some particular order, asks the students questions about each concept in turn, and identities try to learn or not try to learn. "Asking" in this case may be either in person (explicitly), through some indirect vehicle (e.g. a test or homework), or via rhetorical questions (implicitly). We assume continuity across the series of interactions, disregarding the effect of breaks in time between iterations of the interaction. We then partition the simultaneous interactions between the teacher and the students into n two-agent meta-games,

each one involving the teacher and one student interacting over the series of concepts. We assume that the teacher's questions are the same for each student, but the students' responses are taken to be independent from those of other students.

Parameter of this simulation model in level one as follow:

- (1) for each agent i (*student*) has 3 tuple that is (A_i, E_i, M_i)
 A_i is *ability* of student i
 M_i is *motivation* of student i
 E_i is *emotion* of student i
- (2) H_i is level of difficulty (*hardness*) from a given question
- (3) P is progress of student for each concept of difficulty

Whereas, parameter of this simulation model in level two is :

- (1) for each agent i (*student*) has 4 tuple that is (A_i, E_i, M_i, I_i)
 A_i is *ability* of student i
 M_i is *motivation* of student i
 E_i is *emotion* of student i
 I_i is *information* of student i
- (2) H_i is level of difficulty (*hardness*) from a given question
- (3) P is progress of student for each concept of difficulty

3.1 Coding at Level One

In the first level, one pedagogical agent (teacher) interacts simultaneously with many (n) student agents in the same class. The rule is:

- (1) For each agent i , they have chromosome which consist of 3 tuple, that is (A_i, E_i, M_i) .

They have attribute levels as follow:

$$A_i = [0..1]$$

$$M_i = [0..1]$$

$$E_i = [0..1]$$

The example code of agent's chromosome is

A_i	E_i	M_i
1	0	0

- (2) At each of iteration, all student at a given progress, they will presented by same question (same level of difficulty).
- (3) As mentioned earlier, agents are not omniscient; no agent truly knows what action another agent intends to take, but can only judge from what the agent appears to have done. Since the Teacher's effective action (cooperation or defection) depends on the Student's perception, we introduce a rule to

determine the action taken by the Teacher from the point of view of the Student:

if (Student.ability > Concept.difficulty)
Teacher.action ← Defect
else

- Teacher.action ← Cooperate**
- (4) We introduce a rule that relates a Student's motivation and emotion levels to the Student's likelihood of answering a real or hypothetical evaluation question correctly. This rule is central to the dynamic behavior of the lecture model, because it feeds the changes in attribute for iteration, as determined by the response rules, into the next iteration.

- If the Student is both emotionally positive and highly motivated (E high, M high), then she is presumed to have learned the concept well enough to answer correctly no matter the difficulty of the concept, which implies cooperation.
- If the Student is both unhappy and unmotivated (E low, M low), then she is presumed inattentive and will incorrectly no matter the (lack of) difficulty, which implies defection.
- When the E and M states are dissimilar that is, E high, M low or the others possibility, the Student's disposition is less than optimal, giving a probability of answering correctly that is in proportion to the relative difficulty of the concept. We compute this probability delta as:

delta ← (Student.ability/Concept.difficulty)

- If **delta < 1**, the Student may answer incorrectly, (since **Concept.difficulty < Student.ability**, the question seemed hard).
- If **delta > 1**, the Student will answer correctly (the question seemed easy). We express the Student action rule as follows:

If (E low & M low)
Student.action ← Defect
elseif (E high & M high)
Student.action ← Cooperate
else
if delta < 1
Student.action ← Defect
else
Student.action ← Cooperate

- (5) The value of motivation and emotion will be update based on payoff matrix as follow:

<i>Teacher</i>	<i>Student</i>	
	Try to Learn Cooperate	Not Try to Learn Defect
Give Hard Question Cooperate	$M+, E+$	$M-, E-$
Give Easy Question Defect	$M-, E+$	$M+, E-$

3.2 Coding at Level Two

In the second level, one Student interacts simultaneously with many student agents in the same class. The rule is:

- (1) For each agent i , they have chromosome which consist of 4 tuple, that is (A_i, E_i, M_i, I_i) . They have attribute levels as follow:

$A_i = [0..1]$; $E_i = [0..1]$

$I_i = [0..1]$; $M_i = [0..1]$

The example code of agent's chromosome is

A_i	E_i	M_i	I_i
1	0	0	0

- (2) Since the Teacher's effective action (cooperation or defection) depends on the Student's perception, we introduce a rule to determine the action taken by the Teacher from the point of view of the Student:

if (Student.ability > Concept.difficulty)
Teacher.action ← Defect
else

- Teacher.action ← Cooperate**
- (3) We introduce a rule that relates a Student's motivation emotion and information levels as follow:

- If the Student is both emotionally positive and highly motivated (E high, M high and I high), then she is presumed to have learned the concept well enough to answer correctly no matter the difficulty of the concept, which implies cooperation.

- If the Student is both unhappy and unmotivated, uniformities (E low, M low, I low), then she is presumed inattentive and will incorrectly no matter the (lack of) difficulty, which implies defection.

- When the E , M and I states are dissimilar that is, E high, M low, I low, or the others possibility, the Student's disposition is less than optimal, giving a probability of answering correctly that is in proportion to the relative difficulty of the concept. We compute this probability delta as:

$\delta \leftarrow (\text{Student.ability}/\text{Concept.difficulty})$

- If $\delta < 1$, the Student may answer incorrectly, (since $\text{Concept.difficulty} < \text{Student.ability}$, the question seemed hard).
- If $\delta > 1$, the Student will answer correctly (the question seemed easy). We express the Student action rule as follows:
If (E low & M low & I low)
aksi siswa \leftarrow *Defect*
elseif (E high & M high & I high)
aksi siswa \leftarrow *Cooperate*
else
if delta <1
aksi siswa \leftarrow *Defect*
else
aksi siswa \leftarrow *Cooperate*

- (4) The value of motivation and emotion will be update based on payoff matrix as follow:

<i>Student n</i>	<i>Student m</i>	
	Try to Learn <i>Cooperate</i>	Not Try to Learn <i>Defect</i>
Try to Learn <i>Cooperate</i>	<i>M+, E+, I+</i>	<i>M+, E-, I+</i>
Not Try to Learn <i>Defect</i>	<i>M-, E+, I-</i>	<i>M+, E-, I-</i>

- (6) At this level, the student will build their group (team), for example if $n_{pop}=100$ and the number of team is 5, then the number of team in their class is 20. Student will interact with other student. For example students 1 interact with student 2, student 3, student 4, student 6, hence form this interaction, they will get some information from each student who has understanding for the concept difficulty at next iteration.
- (7) If student 1 who cooperate, interact with student 2 who cooperate, then their understanding about a given concept will increase, because their information is increase. The rule is :

If (student 1's action is *cooperate* & student 2's action is *cooperate*)

Understanding (score) student increase

- (8) If student 1 who defect, interact with student 2 who defect, then their understanding about a given concept will decrease, because they do not obtain any information. The rule is :

If (student 1's action is *defect* & student 2's action is *defect*)

Understanding (score) student decrease

- (9) If student 1 has different action choice with the other student, then the understanding (score) will be calculated with rule as follow :

if (student 1's action is *cooperate* & student 2's action is *defect*) or (student action 1 is *defect* & student action 2 is *cooperate*)

Union of ability = (ability of student 1 + ability of student 2)/2;

new difficulty = union of ability /difficulty;

if new difficulty < 1

Understanding (score) of student is decrease

else

Understanding (score) of student is increase

- (10) In lecture traditional model, the concept of difficulty will increase to continue, from easiest concept up to difficult concept. and teacher will continue to give question with the concept regardless of student can follow or not (continue to go forward).

- (11) In lecture feedback model, the concept of difficulty will increase to continue if teacher delimitate sill (efficacy threshold). For the example, if threshold 50%, hence teacher assume to succeed up to difficulty concept

4. Experiment

In this model, one pedagogical agent (teacher) interacted with n number of student simultaneously in a class. Attribute value which consist of ability, emotion, motivate is setting at random from value between 0 and 1 at one level, while at two levels is including information factor. Experiment is taken by using 2 instruction models that is lecture traditional model and lecture feedback model. In both models, each Student gets the same series of questions (i.e., questions of the same difficulty at a given level of progress). In the lecture traditional model, the Student gets a question with a different level of difficulty, but must continue without bothering student can follow or not. This has a negative impact on progress because the harder the question, in the absence of any other changes, the more likely the Student is to become stuck in constant defection (when both E and M are low). While, in a lecture feedback model, teacher give a concept of difficulty for each meeting progressively increase for every student, by paying attention progress of student to percentage of threshold that determined by teacher.

In this research, there are 2 level of learning that is one level and two levels. In one level, the interaction is between student and teacher. In two levels, the interaction is between student and the other student in same class. In one level, both model of instruction, the attribute value is set at random, then

concept of difficulty from easiest up to difficult concept (n step), the number of population size (n pop), and threshold that available only in two levels. In one level, teacher give problem to each student in the form of individually test, with owned ability. But in the two levels, student can discusses (Team Test) with other student after teacher give problem at first level. Student can interact with the other student who try to learn (cooperate) or not try (defect), besides that it can improve by sharing information. In this level, each of students can make team in their class. In this case is made by aggregation, if one student contact with the other student that have different action choice. If student who cooperate interact with student who defect, then their ability will be aggregated. If their ability is still lower to be compared with concept of difficulty, hence the score is decrease.

We have simulated two model of instruction that is traditional lecture model and lecture with feedback model in two levels, with n step=100, n pop=100 and number of team=5 for each level as follow:

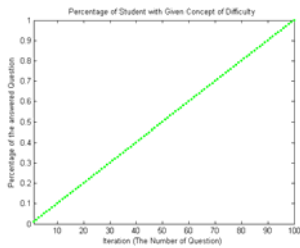


Figure 8. Percentage of questions delivered to the student at *Traditional Lecture Model* (One level)

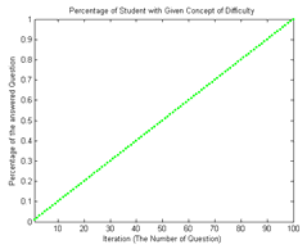


Figure 9. Percentage of questions delivered to the student at *Traditional Lecture Model* (Two levels); Group (team)=5



Figure 10. The Progression of Student's Learning at *Traditional Lecture Model* (One level)



Figure 11. The Progression of Student's Learning at *Traditional Lecture Model* (Two levels); Group (team)=5

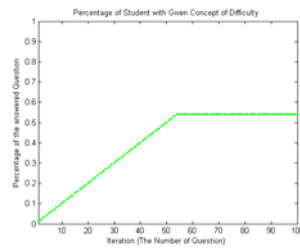


Figure 12. Percentage of questions delivered to the student at *Lecture Feedback Model* (One level)

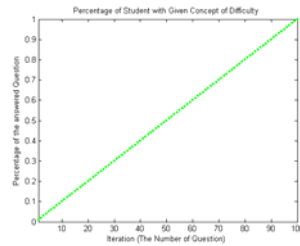


Figure 13. Percentage of questions delivered to the student at *Lecture Feedback Model* (two levels); Group (team)=10

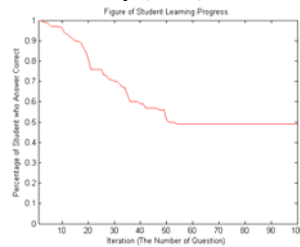


Figure 14. The Progression of Student's Learning at *Lecture Feedback Model* (One level)



Figure 15. The Progression of Student's Learning at *Lecture Feedback Model* (Two levels) Group (team)=10

Lecture feedback (with threshold=50%)

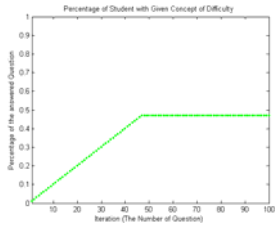


Figure 16. Percentage of questions delivered to the student at *Lecture feedback Model (One level)*

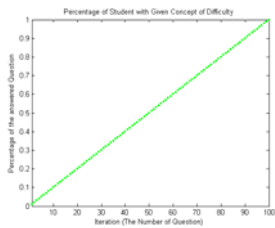


Figure 17. Percentage of Student with given level of difficulty at *Lecture feedback Model (Two levels) with threshold=50% and Number of team=5*

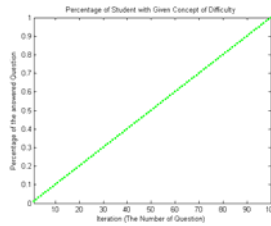


Figure 18 . Percentage of Student with given level of difficulty at *Lecture feedback Model (Two levels) ; threshold=40% and number of team =10*



Figure 20. The Progression of Student's Learning at *Lecture feedback Model (One level) and Number of Team =5*



Figure 19. The Progression of Student's Learning at *Lecture feedback Model (Two levels) with threshold=40% and Number of Team=10*



Figure 21. The Progression of Student's Learning at *Lecture feedback Model (Two levels) with threshold=50% and Number of team =5*

5. Conclusion

Based on experiments which have been done for both model, interaction among student and lecture with feedback are important to improve the student's understanding, because there are information sharing. In traditional lecture at the first level, teacher give problem with increasing concept of difficulty without considering whether student can understand or not, as described in Figure 8, all questions (materials) can be delivered, however, from the view of learning in figure 10 seen that the graph decreases progressively. It means that although teacher can deliver all the problems which increasing concept of difficulty to student, but learning process of student in Figure 10 decreases. This matter is often happened at learning process. While at two levels, student can discuss with their team. In this case, student can update cognitive factors which are owned, like motivation, information and emotion. So that, as can be seen at Figure 11, that is even though the teacher deliver all the question without feedback, there still about 60% of student who are able to follow a question as seen in Figure 12.

In case of lecture with feedback model, teacher gives concept of difficulty by paying attention progress of student. As a result in One level, as described in Figure 12, there is only 50 % of questions delivered by the teacher, it means that teacher only giving problem

with concept of difficulty up to 50% (threshold=50%). While in Two levels, percentage of student who follows the concept of difficulty is up to 100%. This happen because student was discussed with other student in their team. Accordingly, lecture with feedback model with two level of learning which involving team discussion between student and the other student is better than traditional lecture model. At lecture feedback model with two levels are influenced by the number of team of student and the threshold is given by teacher.

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