

# Identity formation/transformation as the process of collaborative learning through AlgoArena

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## Abstract

This paper demonstrates the process of identity formation in the collaborative learning of programming through AlgoArena, which is educational software for learning programming. AlgoArena is a collaborative educational system through which learners can learn programming by participating together in the formation of a community of practice and their identity in it. This paper investigates how a learner's identity is formed and transformed in the process of collaborative learning through AlgoArena. Participatory observation and close analysis of conversation reveals contingent and local characteristics of identity formation, i. e., learning.

**Keywords**—situated learning, software education, identity, interaction analysis

## 1. Introduction

This paper demonstrates the process of identity formation in the collaborative learning of programming through AlgoArena, which is educational software for learning programming. In recent years, a number of educational researchers, teachers, and educational system developers have become aware of the potential of collaborative learning (e. g., Koschmann, 1996). Of the various theoretical foundations for collaborative learning, the authors have relied on situated learning theory (Lave, et al., 1991, Brown, et al., 1988), which focuses on the social characteristics of human learning. The theory claims that learning is the process of participation in a community of practice, or the process of formation of one's identity in the community. Based on this theory, the authors have developed AlgoArena, a collaborative educational system by which learners can learn programming through participating together in the formation of a community of practice and their identity in it. This paper investigate how a learner's

identity is formed and transformed in the process of collaborative learning through AlgoArena.

This paper focuses on qualitative study based on participatory observation and close analysis of conversation in an AlgoArena classroom and demonstrates that (1) the identity of the "programmer" appears in the process of learning, (2) the identity is formed and transformed through local interaction between students, in which they categorize themselves and others as "programmer" or "non-programmer", (3) there is complicated coordination between conflicting identities in the classroom, (4) identity formation is flexible depending on the characteristics of interaction in which they are engaged, and (5) their learning trajectory is shaped by the historical accumulation of the mutual formation of their identity.

## 2. AlgoArena: A tool for the collaborative learning of programming

AlgoArena (Kato, et al., 1995) is a tool for the collaborative learning of programming by novices at the introductory level. This software aims to foster programming skills through collaborative programming activities in which learners are encouraged to cooperate or compete with others. AlgoArena (see Figs.1 and 2) is a simulation of Sumo, the traditional Japanese form of wrestling. Learners are supposed to program the actions of their own wrestlers with a LOGO-based programming language so as to defeat other wrestlers. The learners then have their wrestlers engage in bouts with opponents programmed by other learners or by the teacher. The process of a bout is graphically presented on a CRT monitor. After the bouts have been fought, learners are supposed to analyze the results and incorporate solutions into their own programs. The learners then engage in other bouts. The learners' participation in these iterative programming activities is expected to help them develop their programming skills.



**FIGURE 1.** A sumo bout on AlgoArena

AlgoArena has been planned to be the core for the community of learners. The bout-game situation provided by AlgoArena encourages learners to have bouts with others and to make their wrestlers stronger than the others, thus helping learners to form a community in which the members share their orientation toward increasing the strength of their respective wrestlers. In the world of AlgoArena, winning and losing are completely based on how the programs are made. Consequently, learners are supposed to become highly motivated to improve their programming skills so that they can become winners, i. e., achieve the most admirable station in this community. The orientation given by AlgoArena helps learners form a community of AlgoArena activity in which collaborative learning can occur.

The shared orientation should not be simply attributed to the formation of the community of learners; rather it should provide a foundation of interaction through which the learners can talk about their tasks, problems, and interests, and sometimes face contradictions. The community of learners is shaped continuously and locally through this interaction. It should also be noted that the authors do not claim that the application software solely supports the formation of a community of learners, but that a comprehensive environmental arrangement, including the design of

software, a curriculum, class organization, etc., is needed for the purpose.

### 3. Participatory observation and videotaping in AlgoArena classroom

From an ethnomethodological viewpoint (e. g., Sacks, 1992), identity cannot be considered to be the internal trait of an individual, rather it is locally and mutually established through interaction in which one's identity is displayed, tried, and sanctioned. Identity is made visible through constant participation in this interaction. Of the various factors that relate to the formation of identity, the authors have focused on the conversation in an AlgoArena classroom. Focusing on students' *in situ* conversation should be one of the most effective ways of investigating the process of identity formation, since the process is established through local interaction including conversation, and conversation is easier to observe than other factors.

Participatory observation and videotaping were done in an AlgoArena classroom. The classes were held 12 times during a winter term and forty 9th grade students attended the classes. The class activities included instructions on commands for AlgoArena programming and basic algorithms, free programming activities, and a Sumo tournament held during the last class. Two observers working for a computer company

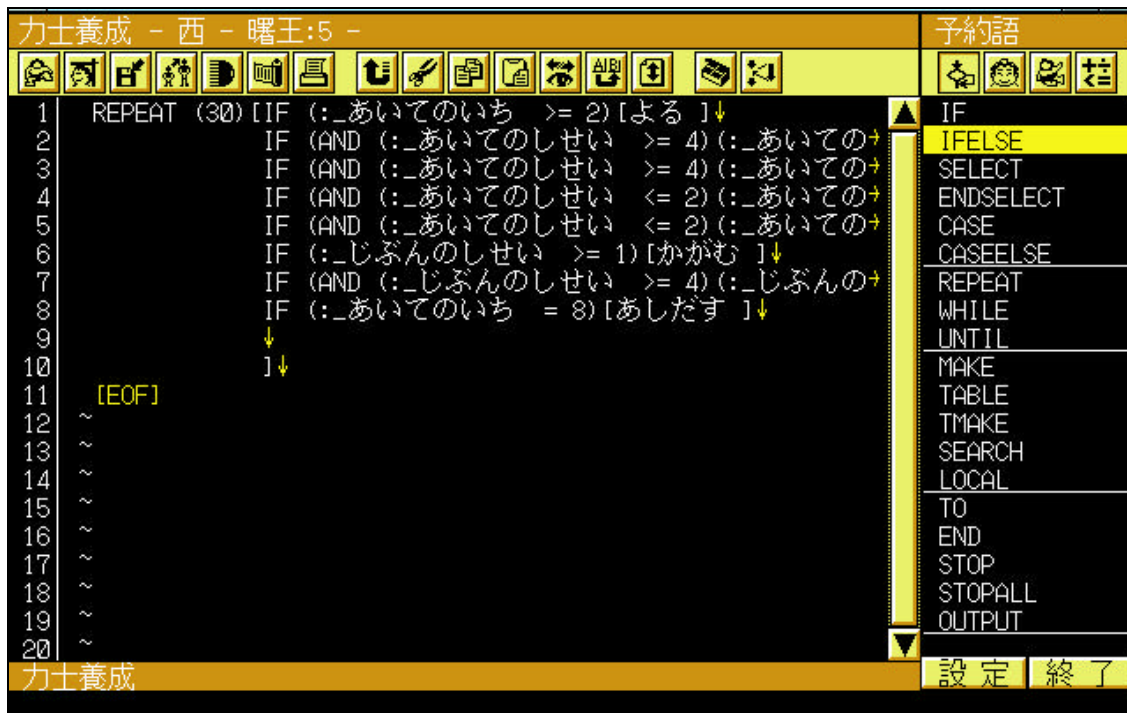


FIGURE 2. The editor screen of AlgoArena

participated in the class as assistant instructors to provide technical support and to bring programming culture into the classroom. In the classroom, one personal computer was shared by a pair of students. A pair of two male students, OH and IM, was chosen for observation; their conversations, actions, and a screen image of their PC were videotaped throughout the classes. The authors, following the teacher's recommendation, chose OH as the target for videotaping because of his fearless demeanor; IM was OH's friend.

In the following section, based on the video data, the authors demonstrate how the identities of these learners appeared and changed, i. e., how their learning was shaped.

## 4. Results and considerations

### 4.1 "We are cool": Voluntary formation of shared activity

On the first day, basic instruction was provided on the AlgoArena system, "action commands", and on simple sequential programming using the commands. The action commands include *move\_forward*, *move\_back*, *push\_forward*, *throw*, and so on. A simple program can be formed by sequencing some of the commands. The following fragment is from the beginning of the second

day, when they were making a simple sequential program.

<Fragment 1>

IM: "Let's minimize the number of commands."  
(1-01)

OH: "Yeah, minimal commands. Then we just need one *move\_forward* here." (1-02)

IM: "We, OH & IM pair, are cool enough to want to try to defeat every wrestler with using the least power. We are different to the other guys" (1-03)

OH: "Absolutely." (1-04)

In this fragment, IM distinguished his team from the others by classifying OH and himself with the word "OH & IM pair (1-03)" and "the other guys (1-03)", and OH accepted IM's display of "team" (1-04): the team working toward winning using "minimal commands"(1-01 and 1-02). The teacher in the class encouraged the students to make strong programs, though never short ones. Given this, they were engaging in the creation of the shared goal for their activity at the very beginning of the class.

This conversation also shows they were making use of the everyday term, "power (1-03)", to talk about their task, even though all events happening in the world of AlgoArena are solely caused by how the

wrestler is programmed. Utilization of the word “power” as a shared artifact to talk about the wrestler indicated that both of them were seeing their task as a Sumo game rather than as programming. Through this conversation their identity as “Sumo game players” was displayed to each other and was confirmed by the very fact that the conversation was carried out by them, thus confirming the sense of a team.

#### 4.2 “No, we should do this stuff”: formation of divergent perspectives

An *IF* command and status parameters were introduced immediately after Fragment 1. The *IF* command is one of the logical control commands. It enables a conditional algorithm like “if my wrestler is bending back, then make it bend forward”. Status parameters are numbers assigned to a wrestler’s specific status, e. g., posture, position, distance from opponents, etc. They are used in conditional programs. Since the parameters are hard to memorize, a status parameter chart that listed all the status parameters was handed out. The following fragment shows the conversation immediately after instruction.

<Fragment 2>

IM: “Well, we don’t need this one, either. We should delete it, right?” (2-01)

OH: “That’s enough. Why don’t we try this now.” [points to Status Parameter Chart] (2-02)

<Fragment 3>

[OH and IM are watching a bout]

OH: “Our wrestler gets pushed back when the opponent moves forward.” (3-01)

IM: “Yeah, the difference in power is pretty clear.” (3-02)

OH: “No! This. We should do this stuff.” [points to the status parameter chart] (3-03)

IM: “Why don’t you pipe down?” (3-04)

In Fragment 2, their shared goal was frustrated. It is apparent that IM’s statement (2-01) was the sequel to the conversation of Fragment 1; IM intended to continue their existing collaboration. However, OH rejected the goal and proposed a new goal, i. e., to program using the *IF* command and status parameters (2-02). At least at this point, it seems OH accepted the *IF* command and status parameters as his thinking tools, although IM did not.

It seems that they began to develop different perspectives on seeing their task after Fragment 2. The conversation in Fragment 3 occurred some minutes after Fragment 2. They were watching a bout, and their

wrestler was pushed back by the opponent. IM attributed this event to the opponent’s “power” (3-02). Although this way of talking about events on the CRT screen seems to have been shared on the first day (see Fragment 1), Here, OH rejected IM’s description of the event and proposed another way of talking about it, i. e., from the viewpoint of status parameters (3-03). This way of seeing an event is an analog of a programmer’s viewpoint. IM rejected sharing this new perspective by asking “Why don’t you pipe down?” (3-04) Here, it is apparent that OH and IM accepted different perspectives. Thereafter, while OH seemed to be absorbed in programming and showed programming ability, IM kept himself insulated from programming activities.

The observed competence of OH is inseparably related to his use of *IF* command and the status parameter chart as his thinking tool. They are artifacts in which the programmer’s ways of thinking and seeing the world are embedded. Accepting these artifacts as tool for his activity leads him to the way programmers see their tasks, i. e., they see a “bout” as a change in status parameters and “making a wrestler win” is seen as an arrangement of these parameters towards a preferable status. As activity theorists have claimed (Engeström 1986, Bødker 1991), human ability should be viewed as the performance of a unified activity system composed of human (subject), artifact, and world (object). Utilization of the artifacts led OH (subject) to see his tasks (object) as program-problems; he solved the problem like a programmer because he was afforded by the constraints of the artifacts. Thus his program competence was able to be observed. In this sense, his competence was not considered to be the emergence of an internal and individual ability; rather it appears through the activity system of which he is a part. Moreover, by using these terms in his talk, his identity as a programmer, i. e., a person who talks about his tasks in technical terms, is displayed and ready to be tried. As Fragment 11 (11-05) shows, programming-related terms were used as resources for identity formation by OH and IM.

In the same way, IM’s lack of competence as a programmer should not be attributed to a lack of internal ability. Instead, his apparent lack of competence resulted from his involvement with a different sequence of activity where he presumably established a different type of competence using different artifacts.

The following fragment shows how two different perspectives in one team facilitates learning as an expansion of one’s view.

<Fragment 4>

[IM and OH are talking about OH's wrestler]

IM: "Your wrestler is strong, but he seems to be going through the same fixed pattern again and again. He only has one "waza" (Sumo technique)." [4-01]

OH: "This is all I can do with him." [4-02]

IM: "Don't you want him to be more appealing, with a more elegant way of winning?" [4-03]

OH: "Well, I think it is impossible to put a lot of different techniques into one program." [4-04]

IM: "But I really think it would be more appealing if your wrestler could defeat others by using a lot different techniques." [4-05]

In this fragment, IM pointed out that OH's wrestler had just one Sumo technique [4-01]. IM's statements were perhaps based on a non-programmer's viewpoint; that is, IM might have been expressing his request without any ideas on how the program was made for that purpose. OH's answer [4-02] to IM was reasonable given OH's understanding of programming at the point. Although it is actually possible to install many techniques in one program, OH's understanding at this stage restricted his ability to view the problem, thus OH came to the conclusion that putting many different techniques into one program is impossible. OH was faced with learning stagnation. He was holding a view formed by his restricted understanding and making a decision based on that view, even though there was an opportunity to expand his view by improving his understanding. IM's statement that it would be more appealing if many techniques were used to defeat other wrestlers had the potential to undermine OH's fixed view and to lead OH to expand his understanding.

This episode demonstrates that divergent perspectives in a group might sometimes facilitate collaborative learning. Collaborative learning is not simply learning through sharing, but it also includes dialectic expansion through contradictions between divergent perspectives.

#### 4.3 "You are a total computer nerd": Identity formation with membership category device

On the third, fourth, fifth and sixth days, OH was trying to make a complex program incorporating *IF*, *IFELSE*, and *REPEAT*, while IM was fooling around chatting, watching other bouts, and teasing his friends. The following fragment is from the fifth day.

<Fragment 5>

OH: "I have been defeated and defeated" (5-01)

IM: "You can not win?" (5-02)

OH: [starts to browse the manual]

IM: "I, I think I don't want to work for a computer-related company. It's boring." (5-03)

This fragment demonstrates the formation of divergent identities. The statement, "I don't want to work for a computer-related company (5-03)", following OH's browsing the manual, generated a boundary between "people who are suitable for computer-related work (people who looks into a manual to develop programs)" and "people who are not"; IM himself was put in the latter category. At the same time, the statement put OH, who was browsing the manual, on the other side of the boundary. OH could protest IM's categorization, but he did not take any action against IM, thus IM's display of their identity was sanctioned by his silence. Their identity was mutually and locally formed through this very conversation. Fragment 6 shows another example of identity formation.

<Fragment 6>

[OH had been talking with Suzuki (observer) about a program technique, and Suzuki left]

OH: "Shit! I made this program last night." [shows his memo to IM] (6-01)

IM: "You are a total computer nerd." (6-02)

OH: "Well, I just had a lot of free time last night." (6-03)

IM: "You don't have to make excuses." (6-04)

OH: "I am not." (6-05)

IM: "You are changing bit by bit while you don't notice it" (6-06)

OH: "Oh, am I? So I'm in danger, am I?" (6-07)

[Some minutes passed while OH was editing program]

IM: "Hey, you showed me the memo after the teacher.. the man left us?" (6-08)

OH: "Of course. I didn't want to show my memo to him. I hate him to see that I am deeply involved in this activity." (6-09)

In this fragment, IM labeled OH as a "computer nerd (6-02)". It could be said that the categorization "computer nerd" supposedly overlaps with "programmer" in the sense that both categories refer to a "person who engages in computer-related activities". Through this categorization, a boundary between "computer nerd (i. e., programmer)" and "non-computer

nerd (non-programmer)” was generated and OH was put on the “computer nerd” side. OH’s response was ambivalent: OH first said “I am not (6-05)” to protest the label, but in his next response it seems he accepted the label saying “Oh, am I? (6-07)”, however he was also expressing that he had not been a “complete computer nerd” yet by delivering “So I’m in danger, am I (6-07)”. Through this conversation, OH’s identity, i.e., “computer nerd (but not complete)” was constructed, and IM appeared as a “non-computer nerd” relatively. It should be noted that what they did here was not “fit themselves to a certain identity”, but it was the collaborative and local generation of identity using the term “computer nerd” as a “membership category device” (Sacks, 1992). The appearance of a computer-related category – “computer nerd” – in their conversation implies that AlgoArena created an occasion for categories such as “computer-oriented person” and “computer-related ability” were relevant, and learning in the environment was related to the establishment of identity as a “computer-oriented person”.

The last exchange in Fragment 6 (6-08,6-09) implies intricate identity formation in the AlgoArena classroom. “The man” in IM’s statement is one of the observers. The observer was probably seen by IM and OH as a “teacher-side person”. IM’s rewording, “the teacher.... the man”, supports this assumption. Given this, what IM meant by his statement was: “did OH intentionally avoid showing his memo to the teacher-side person, the observer?”. This question was answered “Yes” by OH. In the response, OH also expressed aversion to being seen as an enthusiastic programmer by the observer who was a teacher-side person (see 6-09). This exchange indicates the existence of a “brat community” which bids defiance of authorized class activity, and regards good students as “*not cool*”. What they established through the exchange was the formation of a boundary between “conforming student” and “brat”, and they confirmed each other’s identity as “brat”.

The fragment shows that at least two kinds of identity coordination were relevant in the AlgoArena classroom. The first is between “programmer” and “non-programmer”, the second is between “conforming student” and “brat”. In the classroom, the identities as “programmer” and “conforming student” roughly overlapped, because programmer-like ways of seeing the world and programmer’s artifacts were presented by the teacher. In this situation, forming one’s identity as a “programmer” intrinsically endangered OH’s identity as a “brat” because behaving like a programmer would have been seen as complying with teacher side expectation. What OH tried to do in the fragment was

maintain his identity as a “brat” while displaying himself as a “programmer”. “Shit (6-01)” in the first line is also good proof of the complex identity coordination in which OH was engaged. He displayed his enthusiasm for programming by showing his moonlight programming, but at the same time, he tried to confirm his “brat” identity by using a vulgar expression when he happened to display his enthusiasm. Identity formation in the classroom was not a simple linear process. It was composed of complicated coordination between conflicting identities. The following fragments imply the same type of identity coordination.

<Fragment 7>

IM: “Isn’t this the strong wrestler?” (7-01)

OH: “No, it’s a new one. His name is Toryushin (name of the wrestler). Hey I hate this silly game.” (7-02)

<Fragment 8>

IM: “IU (another student), tell me how to install Waza (Sumo technique). I want Bakabon (name of his wrestler) to be the strongest.” (8-01)

IU: “Bakabon” (8-02)

IM: “How silly I am to play this damn game.” (8-03)

In both fragments, the students labeled their activity as “silly” (7-02, 8-03). It is interesting that the statements are not coherent in terms of their attitude toward AlgoArena activity, that is, OH in Fragment 7 were devising a new wrestler (7-02); IM in Fragment 8 wanted to make his wrestler the strongest (8-01). The identity coordination between “conforming student” and “brat” could be one possible answer to the question: “Why did they have to talk negatively about AlgoArena activity although they were actually enthusiastic?” Displaying themselves as enthusiastic programmers may have endangered their identities as “brats”, so they had to reinforce their identities by labeling their current activity as “silly” when they happened to show their enthusiasm. Identity formation in the classroom was not a simple linear process. It was composed of complicated coordination between conflicting identities.

#### **4.4 “You should be the one who’s ashamed”: Two kinds of strength**

On the seventh day, IM stated: “I am going to make my own program, so after I do let’s have yours and mine have a bout.”. He made his own program. Although it was a simple sequential program, “*move\_forward, push\_forward, move\_forward, push\_forward....*”, it was strong against OH’s

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REPEAT (30) [move_forward Defense]

TO Defense
IFELSE (:_his_hand = 2)[disturb_hishand][
IFELSE (:_my-posture <= 2) [bend_forward][
IFELSE (:_my-posture =4) [bend_back][
IFELSE (:_my-posture= <=2) [move_forward][Offense]
]
]
]
END

TO Offense
IFELSE (:_his_hand = 2) [disturb_hishand][
IFELSE (:_his_posture =4) [slap_down][
IFELSE (:_my-hand =2) [throw][
IFELSE (:_distance= 1) [grasp_mawashi][push_foward]
]
]
]
END

```

**FIGURE 3.** Program made by OH

program. OH was not able to defeat IM's wrestler no matter what he did for two days. (It would be fair to say that IM's wrestler was "accidentally" strong.) Figures 3 and 4 show their programs. The following conversation followed after OH's wrestler was defeated by IM's several times.

<Fragment 9>

IM: "You have to admit my program is pretty good. You should study it very carefully." (9-01)

OH: "You really get the better of me here." [seeing IM's program] (9-02)

IM: "This is the program that beat yours all to hell." (9-03)

OH: "But all it has is *move\_forward* and *push\_forward*!" (9-04)

IM: "No, it also has a *move\_back*. It uses it to feint" (9-05)

OH: "I'd be ashamed to win with a program like yours." (9-06)

IM: "YOU should be the one who's ashamed. Who won, anyway?" (9-07)

This conversation shows us their divergent perspectives. OH implied that IM should be ashamed of his program, even though IM's wrestler defeated OH's time and again. This statement indicates that OH was not seeing the program from the viewpoint of simple

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move_forward
push_forward
move_forward
push_forward
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move_forward
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push_forward
move_forward
move_forward
move_forward

```

**FIGURE 4.**  
Program made by IM

winning and losing; his view of the task would have been “to win by means of a well-planned strategy, not by accident”. OH did not respect IM’s wrestler, because it was a very simple sequential program. However, IM was seeing his task from the simple viewpoint of winning and losing. From his perspective, OH’s wrestler that can not win should have been ashamed. Through this conversation, OH’s and IM’s identities, i. e. “OH as a programmer” and “IM as a non-programmer” were recreated.

#### 4.5 “I am becoming a computer nerd”:

##### Relative characteristic of identity formation

On the ninth and tenth days, OH was absent from the class. During his absence, IM started to revise his program using *IF*, *IFELSE* and *REPEAT* commands. During this period, IM spent much time with IU, asking him questions and discussing various points with him.

IM had changed drastically during these two days. He seemed to have started behaving like OH, i. e., like a “programmer”. He browsed the manual frequently, trying to use commands and to figure out the reasons for his defeats. What caused the change? One possible answer is that the new human relationship constructed another display of competence. The newly established “IM-IU” relationship was apparently different from the “IM-OH” relationship. OH was capable in terms of programming; he quickly understood commands and algorithms, and he was one of the most advanced learners in the classroom. Consequently, in the “OH-IM” relationship, IM may have appeared to be a relative “non-programmer”. However, IU was a slightly more advanced learner than IM; he sometimes gave IM information about programming techniques, although sometimes he asked IM questions. Thus, in the “IM-IU” relationship, IM was able to display himself as a “programmer”. As a result, IM appeared as a “colleague programmer”. Fragment 10 indicates the transformation in IM’s identity in the new human relationship.

<Fragment 10>

IM : “I’m going to install a lot of fighting strategies into this program. Now, where can I find them?”  
[picks up the manual book and browses through it] (10-01)  
IU: \_i?? unclear ??) (10-02)  
IM: “Hey, I guess I am becoming a computer nerd!” (10-03)  
IU: “Are you?” (10-04)  
IM: “I guess so. I am really getting into this stuff.” (10-05)

This fragment apparently shows a transformation in IM’s identity from a “non-programmer” into a “programmer”. Through this conversation in which IM labels himself as a “computer nerd”, IM’s identity as a “programmer” is indicated and established (compare with Fragment 6). This transformation may be possible in an “IM-IU” relationship, where IM is a co-worker who has almost the same ability as IU. However, IM must not have been able to display himself as a “computer nerd” in the “OH-IM” relationship, because OH was a much more advanced programmer. It is clear that one’s identity is flexible, depending on the pattern of interaction in which the person participates.

#### 4.6 “My forward-and-push days”: Talking about the history of learning

On the eleventh day, the students programmed their wrestlers for the Sumo tournament planned for the twelfth day, the last day of the class. OH returned to the class on the twelfth day, and the “OH-IM” pair was reunited. In the tournament, IM’s wrestler which had been revised using many control commands was making a sequence of victories. Conversely, OH’s wrestler could not win, and he tied in all his bouts. In the following fragment, IM and OH are talking about the strength of IM’s wrestler.

<Fragment 11>

IM: “Hey, I’m the only one whose wrestler has been winning a lot of bouts in a row.” (11-01)  
OH: “Is that right?” (11-02)  
IM: “Yes, I am running up a string of consecutive victories” (11-03)  
OH: “Good for you.” (11-04)  
IM: “I changed the content of my program a lot while you were away, using *IFELSE*s, tons of them, I..” (11-05)

It is notable that IM attributed the strength of his wrestler to the incorporation of *IFELSE* commands (11-05). This statement indicates that IM had formed a new viewpoint that explained the strength of a wrestler in terms of how the program was made, i. e., the programmer’s perspective. Through this exchange in which the strength was talked based on the incorporation of *IFELSE* commands, IM and OH were able to appear as “programmers” together. The word “*IFELSE*” was functioning as a shared artifact allowing them to talk about their tasks in a way a programmer would, and through utilizing this artifact in their conversation, they mutually confirmed their identities as programmers.



<Fragment 12>

[OH and IM are going to have a bout]

OH: "I'm definitely going to win this time. hhhha"  
(12-01)

IM: "Don't be too sure!" (12-02)

OH: "Maybe, you're right" (12-03)

IM: "But, in my forward-and-push days, I was hhh"  
(12-04)

OH: "hh, forward-and-push days, yeah." (12-05)

IM: "My wrestler has gotten a lot stronger than before,  
don't you think so?" (12-06)

OH: "Yeah, it's better than the previous one." (12-07)

In this fragment, IM looked back on his previous programming style by labeling it "forward -and-push days"(12-04). By this statement, IM's simple sequential programming style was transformed into a relic of the past, and IM's present status, i. e., advanced programmer, was highlighted. Through talking about IM's "forward-and-push days" together (12-04, 12-05), they made sure that both of them were sharing the same position: They are now advanced programmers together. In short, their shared identity as "advanced programmers" was formed on the foundation of their learning "history"; their learning trajectory was shaped by the historical accumulation of the mutual formation of their identities. It should be noted that the "history" was not a stable entity, but was formed through this very exchange, and it was utilized as a resource to form their "now".

The last exchange in this fragment (12-06, 12-07) is inconsistent with the fact that OH had never been able to defeat IM's "forward-and-push" wrestler no matter how hard he tried. This exchange shows that they were sharing the same perspective in viewing their activity. That is, both OH and IM were seeing their activity as "producing a strong wrestler through programming techniques" rather than "producing a strong wrestler through any means". From this shared perspective, IM's new program including "tons of *IFELSEs*" was seen as "stronger" than the previous program which was simply strong. This shared perspective is their learning achievement at this point in time.

The important thing is that their achievement was established through a continuous collaborative enterprise in which they had various conversations on their goals and tasks, their own and other's situations, their learning history, etc.

## 5. Conclusion

We discuss the AlgoArena system and a qualitative study in the AlgoArena classroom. The study revealed

that (1) the identity of the "programmer" appeared in the process of learning, (2) an identity was formed and transformed through local interaction between students, in which they categorized themselves and others as "programmer" or "non-programmer", (3) there was complicated coordination between conflicting identities in the classroom, (4) identity formation was flexible depending on the characteristics of the interaction in which they were engaged, and (5) their learning trajectory was shaped by the historical accumulation of the mutual formation of their identity.

In conclusion, identity formation in the AlgoArena classroom was not a simple trajectory toward a fixed identity, but the process of participation in on-going formation and the transformation of identity through local interaction; AlgoArena provided learners with abundant and varied resources for the mutual formation of identity, i. e., learning.

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