Modeling Laborer's Group Learning Processes in Construction

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Abstract

Construction industry still requires a lot of laborers to perform a project despite of advance in technologies, and improving labor productivity is an important strategy for successful project management. Since repetitive construction works exhibits learning effect, understanding laborers' learning phenomenon therefore allows managers to have improved labor productivity. In this context, previous research efforts quantified the learning effect of 'individual' laborer, though numerous construction works are performed in group. In other words, previous research about labor learning assumed that the sum of individual's productivity is same as group productivity. Moreover, managers in construction sites need understanding about group learning behavior for dealing with labor performance problem. To address these issues, the authors investigate what variables affect laborers' group level learning process and develop the system dynamics model as a basic tool of productivity estimation regarding group learning. Based on the result of this research, it is possible to understand forming mechanism of learning within the group level. Further, this research may contribute to maximizing laborers' productivity in construction sites.

Keywords: Group Learning, Labor Productivity, Human Behavior, System Dynamics, Construction

Body of Paper

Introduction

Research Background

Construction industry still requires various laborers to perform a project employing 11.1 million laborers in US (CPWR 2013) despite of advance in technologies. Therefore, improving labor productivity is a key strategy for successful project management in construction (Oglesby et al. 1989). To forecast and improve labor productivity in construction, learning curve theory has been applied to labor-intensive tasks (e.g., concreting, re-bar fixing, masonry etc.). Learning curve theory is based on the ability to learn from past experience and it is a basic principle of human nature (Jarkas 2010). Especially, construction tasks are generally repetitive and they fit with learning curve effect, which is a phenomenon that a laborer becomes more productive doing a task when he or she performs the task repetitively (Adrian 1995).

Though previous studies effort to investigate and apply the learning curve effect to construction tasks, the studies mainly focus on 'individual level' of learning. This can cause misunderstanding about learning effect that labor productivity always improves when laborers learn skill. In fact, numerous construction works consist of group (crew) works and rarely done by an individual in isolation (Adrian 1995). In other words, 'group level' learning should be further investigated to find out how laborers' learning is reflected in productivity improvement. Also, few studies have been modeled group learning process for practical use in construction, and only deal with its manifestation results. Without investigating the group learning process, managers may miss the managerial points, which can improve the laborers' learning and productivity.

Figure 1. Examples of Labor Intensive Tasks in Construction

Research Questions

In construction industry, 'learning curve effect' is usually applied when analyzing the laborers' productivity. However, there is a considerable gap between theory and actual productivity (Figure 2).

The graph shows that labor productivity does not increase as much as the learning rate, and the learning theory overestimates the labor productivity. The authors raise questions that why a laborer's skill learning is not fully reflected to productivity (i.e., despite all laborers' high level of skill, their productivity is often lower than expected). Also, according to the awareness of a laborer himself/herself as an individual or as a group member, the labor productivity can be manifested differently.

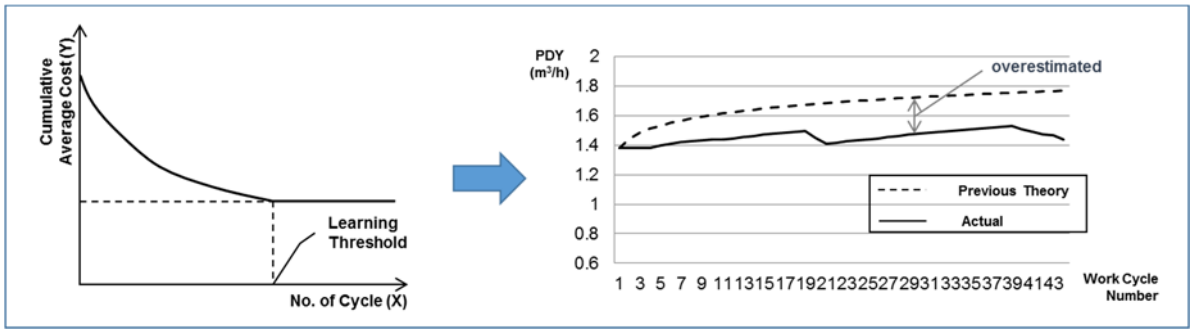

Figure 2. Considerable Gap between Theory vs Practice (adapted from Lee et al. (2015))

The other question is how 'learning' and 'productivity' can be defined. Is 'learning activities' always improving the productivity? If not, managers should know how they can maximize the productivity with laborers' learning.

Research Objectives and Framework

The objectives of this research is to investigate the group learning effect, and analyze its development and manifestation process in construction. Also, this research develops a system dynamics simulation model as a tool of productivity estimation regarding group learning. To achieve these objectives, this paper defines a concept of group learning in construction and model its concept for testing the model variables' influences. The authors expect that the end results of this paper help to understand a dominant but invisible phenomenon using visible tools. In further studies, the authors will analyze the group learning processes and effect, and suggest managerial implications to construction site managers.

Previous Research

Work Group Learning

Group learning in work group has been mainly studied in social science. According to theory, a group learns naturally by itself within their environment (Argote 1993; Jaques 2002; Wilson et al. 2007; Sessa and London 2008). In other words, when a group is formed to perform tasks, the group naturally learns as a living system (Jaques 2002). Group learning is a dynamic process in which learning processes, the conditions that support them, and group behaviors change as the group learns (Argote 1993; Kasl et al. 1997; Sessa and London 2008). There are three perspectives of work group learning: (a) a process of individuals getting a full understanding of a task or situation, and conveying that learning to others (Sessa and London 2008), (b) the collective or synergetic information processing as a group acquires new understanding or knowledge (Hinsz et al. 1997; Day et al. 2004; Kayes et al. 2005), (c) a learning how to work with others (Kozlowski et al. 1996; Vera and Crossan 2004; London et al. 2005; Sessa and London 2006).

Though managers usually expect that group learning always has positive effect and improve the situation, the results of group learning can be manifested in various ways (i.e., group learning can improve or deteriorate the situation). In detail, group learning can sometimes lead to unexpected outcomes such as forming dysfunctional habits or interaction that are counterproductive (Sessa and London 2008). Figure 3 describes the possible various results.

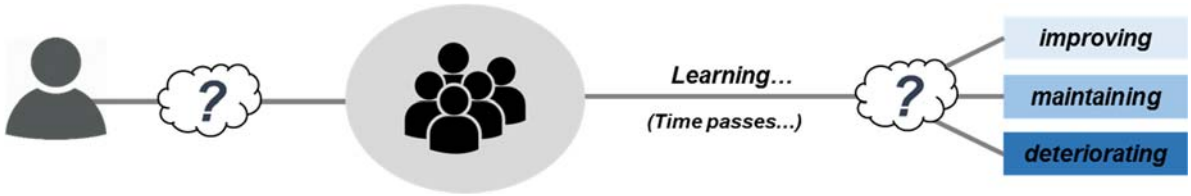

Figure 3. Possible Results from Group Learning Process

"Ringelmann effect' is a typical example of dysfunctional or counterproductive effect of group. Ringelmann effect is defined as the group of workers all become less productive in groups (Forsyth 2005) and this reduction of productivity is called as 'social loafing' (Williams et al. 1981). Ringelmann identified that the main cause of productivity reduction is the 'coordination losses', lack of simultaneity of their efforts (Ringelmann 1913). Also Ringelmann (1913) speculated that people may not work so hard when they are in groups (Forsyth 2005). The positive effect of group learning can affect when groups may urge the members with less ability to work harder, and the members may respond with increase effort (Forsyth 2005). This effect is called as 'Köhler effect'. The inferior member may be aware of work pressure to do tasks well.

The above two effects have one thing in common that they occur when group members are aware of their group and other members. Depending on the strength of these effects, group learning can improve or deteriorate the group productivity. Thus, managers should understand the group learning processes and reinforce the positive effect of group learning.

Group Learning in Construction

Learning curve theory in construction is generally defined as 'an individual laborer's learning' from task repetition. According to the very definition of learning curve theory, managers should track a laborer every single day when they want to know the laborer's learning rate and its effect. However, getting an individual laborer's learning information is impossible and also useless for management. This is because 1) construction tasks in sites are generally performed by groups (e.g., steel work, masonry work, etc.) and 2) productivity improvement from learning can only be manifested within group level. As a result, previous research (Oglesby et al. 1989; Adrian 1995; Jarkas 2010) generally assume that a group learning is identical with the sum of each individual's learning. However, this assumption can cause errors to forecast the labor productivity (Figure 2). For example, though managers hire a group of skilled laborers to improve the productivity, their productivity is not improved as expected. It can be an evidence that learning in construction occurs in group level. Therefore, learning development process in construction sites should be further investigated in group level.

Construction tasks performed by groups have common characteristics. The authors suggest typical four characteristics as follows (Figure 4).

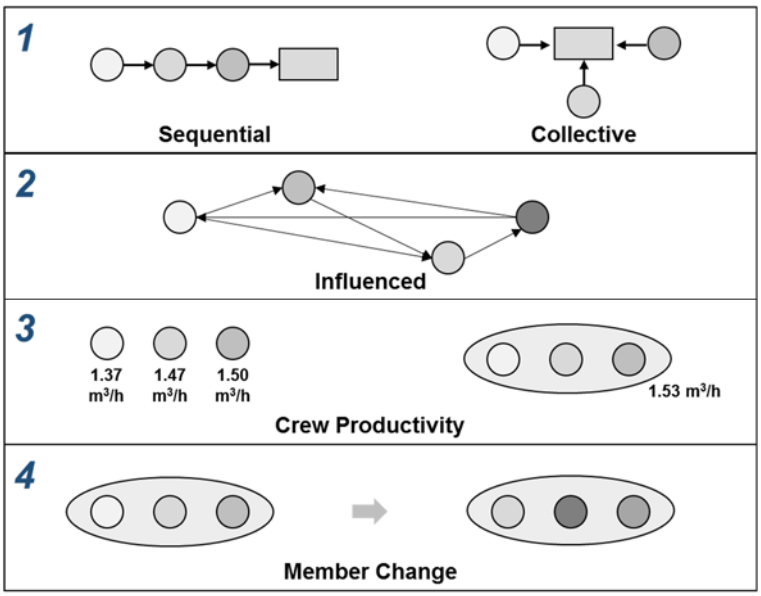

Figure 4. Group-based Tasks' Characteristics in Construction

1) Group-based tasks progress sequentially or collectively.
2) Other members' working behavior or performance can affect my task.
3) Productivity of a group is more meaningful than every individual's productivity.
4) Group members are frequently changed for various reasons (e.g., turnover or new hiring (including foreign laborers)).

The four characteristics can affect group learning development or manifestation process, and they will be applied as task rules in developing models.

Two Types of Group Skill Learning

Group learning can be categorized into two types in detail, 1) individual's learning in the context of group (so-called group context learning) and 2) actual group learning. First, group context learning is defined as an individual laborer can learn by observing other members or group environment. Observing other group members or group environment is a result of group performance and this type of learning can influence each individual's performance. Herriott et al. (1985) mentioned that how one actor can supplement learning from direct experience (i.e., individual skill learning) through diffusion of experience by copying others (Ryu et al. 2005). The contents of group context learning include both productive and unproductive (i.e., other members' know-how, task-relevant experience or counterproductive habits etc.), which are generated from group learning process. In this research, individual laborer can learn from others by informal communication (e.g., observing or just working together).

Actual group learning is literally a result of learning among group members. In this process, information or knowledge that group members have is directly shared in the group and the result of this process is reflected to group environment. A group-level learning is developed by formal communication (e.g., directly transferring or sharing activities). Ingram and Simons (2002) described that groups facilitate the transfer of experience among members through three specific mechanisms: 1) by increasing the opportunity for transfer, 2) by increasing the motivation for transfer, and 3) by increasing the capability of organizations to successfully apply the experience of others. Through the above process, productive or counterproductive learning behaviors are generated and they can influence an individual laborer as a group culture or environment (group context learning).

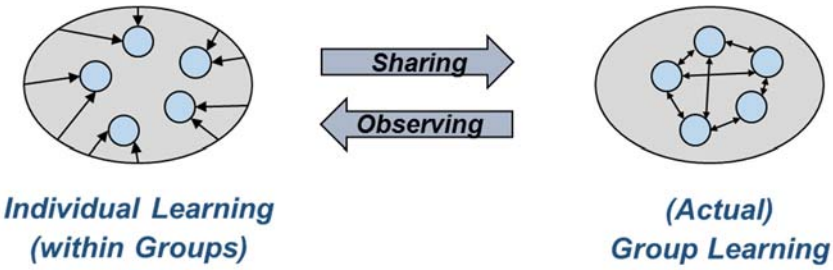

Figure 5. Two Types of Group Learning

Skill Learning vs Productivity

In numerous research, 'skill learning' is considered as analogous to 'productivity' (i.e., when a laborer learns skill, his/her productivity improves). However, skill improvement does not always lead to productivity improvement. In other words, there can be the adverse effects that a laborer does not perform his/ her best efforts even he/she has learned the work skill from group. Figure 6 presents the learning process and its possible results.

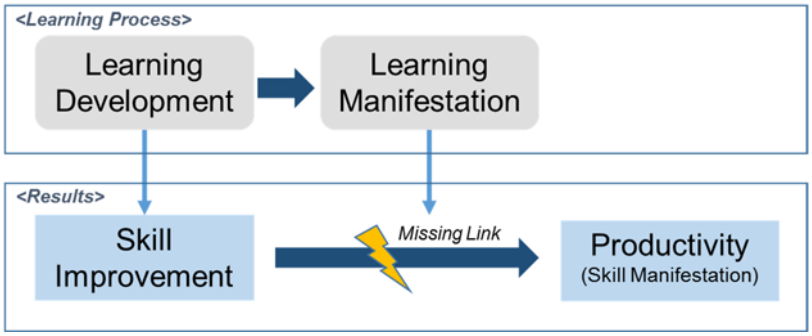

Figure 6. Detailed Relation of Learning and Productivity

In the context of the group work, a laborer's productivity can be affected by the group behaviors. Moreover, the individual's skill level or productivity cannot be measured or identified in construction site, and only the group productivity is visible. The authors suggest that the relation of the 'learning' and 'productivity' should be clearly defined.

System Dynamics

This research takes system dynamics modeling as a tool of modeling group learning processes. System dynamics has advantage when analyzing feedback process (Sterman 2000), such as the group learning behaviors. Also, group learning manifestation results (i.e., productivity) from group learning state changes as time passes and this state change can be analyzed as stock variables. Moreover, system dynamics modeling is suitable for analyzing human behavior with complex interactions among factors (Sterman 2000; Williams 2002; Harrison et al. 2007) and presenting invisible phenomenon. Numerous research modeled the human learning behavior using system dynamics (Sterman 2000; Morrison 2008) to provide the comprehensive solutions. Therefore, this research employs the system dynamics modeling to investigate group learning, the complex and dynamic processes.

Group Learning Process Model Development

Model Framework

This research builds a system dynamics model to estimate the group learning effect and its influence to productivity. The authors suggest a model framework describing the group learning process, from development to manifestation.

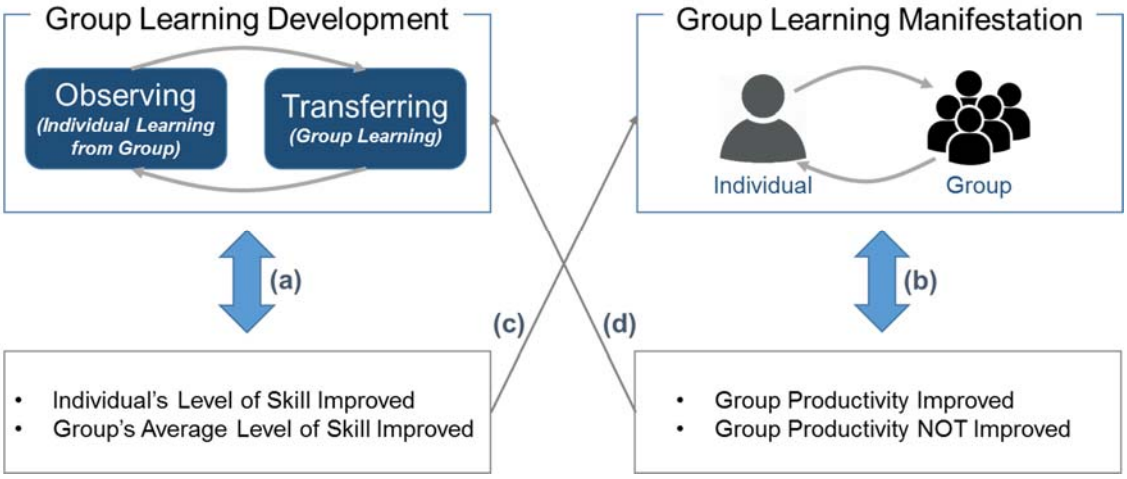

Figure 7. Model Framework

Group learning development and manifestation processes occurred independently and the results of processes affect each other. Figure 7 presents these four processes. Group learning development consist of two activities, observing and copying other members, and transferring his/her task skill to other members. As a result, each individual laborer's level of skill would improve and group's average level of skill also improve (a). Group learning manifestation means a process that skill is manifested to productivity, and it is triggered when individual is aware of group behavior. The result of this process can be variable, and group productivity may improve or not. These group behavior results are also reflected to individual's behavior (b). When laborers perceive that individual and group's level of skill is improved or not, it can affect an individual's work behavior (c). Also, how laborers perceive the group productivity can affect group learning development process (d).

Model Assumptions

The model has four assumptions for modeling: a) the number of group members are five. The effect of group size is not considered in this model. b) the task type is additive (i.e., all group members have same tasks and their works are collected together, such as masonry work). c) individual and group's skill is always increased, not decreased. The authors assumed that once the skill is learned, it is never forgotten or decreased. Finally, this model only includes the learning effect from group, not individual level of learning.

Group Learning Development Model

The process of the skill learning development from group is called as 'group learning development'. As mentioned above, the individual laborer's skill learning from group occurs with two types of activities, 'observing others' and 'transferring'. The skill improvement from group is caused by awareness of other members' level of skill and comparing his/her skill with group. Since the level of skill is an invisible concept, a laborer perceives the group's skill with 'average of group productivity' by guessing how much work has done as the group. The skill learning is developed when the individual laborer perceives that 'our group is more or less skilled than me.'

When a laborer perceives that he/she is inferior to other members, he/she gets the 'willingness to copy' others. The larger perceived gap between individual and group's skill is, the more willingness to copy increases and it leads to increase of observing activities. 'Individual's awareness to others' can also affect to willingness to copy others. For example, an individual laborer is not sensitive to others, he/she does not learn from others even he/she is poor worker.

When a laborer perceived that he/she is superior to others, he/she gets competence and perceives high level of 'the psychological safety' from group. The psychological safety is a sense of confidence that the group will not embarrass, reject, or punish someone for speaking up (Edmondson 1999). The higher the level of psychological safety of the group, the member sense a confidence for sharing his/her opinion and it leads to increase of transferring activities. With transferring activities, superior member transfers his/her experience and knowledge to other members. When an individual perceives that group climate is positive, the perceived psychological safety from group increases.

According to the strength of the above two activities, skill improvement rate from group learning (how fast the laborers achieve maximum level of skill) is defined.

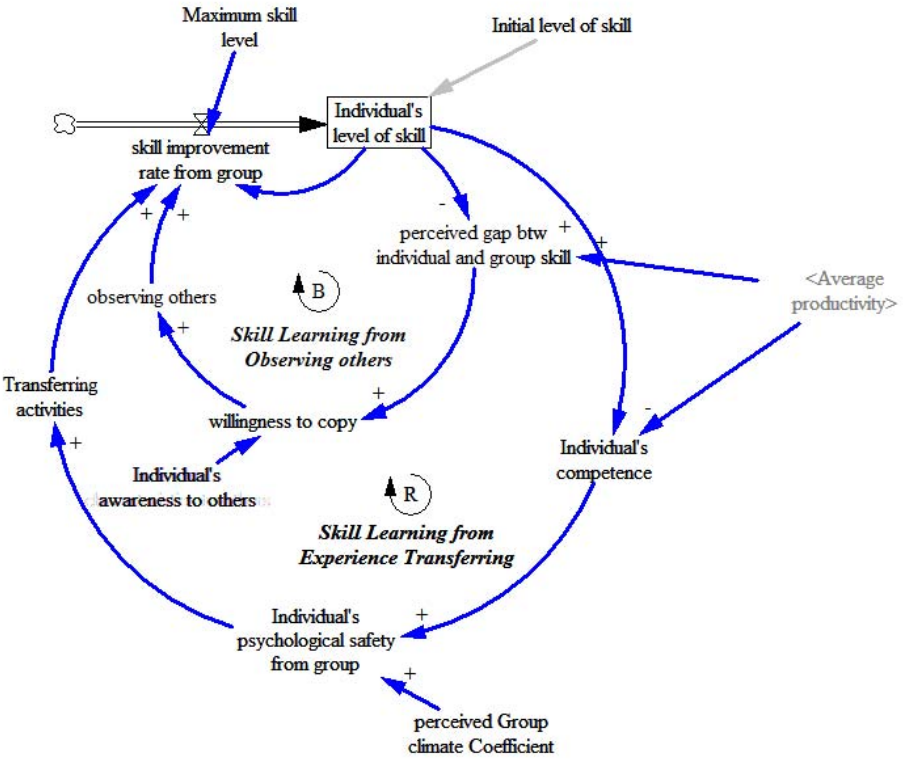

Figure 8. Model for Group Learning Development

Group Learning Manifestation Model

The process of the skill learning manifestation in group is called as 'group learning manifestation'. The results of this process are presented as the 'productivity'. In this process, the most important factor is the individual laborer's decision that he/she will fully perform his/her skill or not. The decision is made from the 'perceived productivity gap between plan and actual'. When an individual laborer perceives that 'our group's productivity is high enough to achieve the group's plan', he/she may decide that 'I do not have to work fast'. It leads to 'social loafing' and the more the laborer loafing around is, the laborers' actual work hours decrease. Though the site managers expect that all laborers work for eight hours a day, the laborers' actual work hours can be much less than expected.

The opposite can also happen when the laborer perceives that 'our group's productivity is lower than plan', they perceive the work pressure for catching up with the plan. It leads to the laborer work faster and the increased work hours from this decision is defined as 'boosting hours' in this model. When laborers make decisions of their work efficiency, the personal characteristics are also affected to the decisions. Each characteristic is defined as 'loafing coefficient' and 'work pressure coefficient'. For example, when a laborer is more sensible to work pressure, he/she has strong possibility to work fast and may not have a loaf.

According to the strength of the above two activities, each laborer's and the group's productivity from group learning is defined.

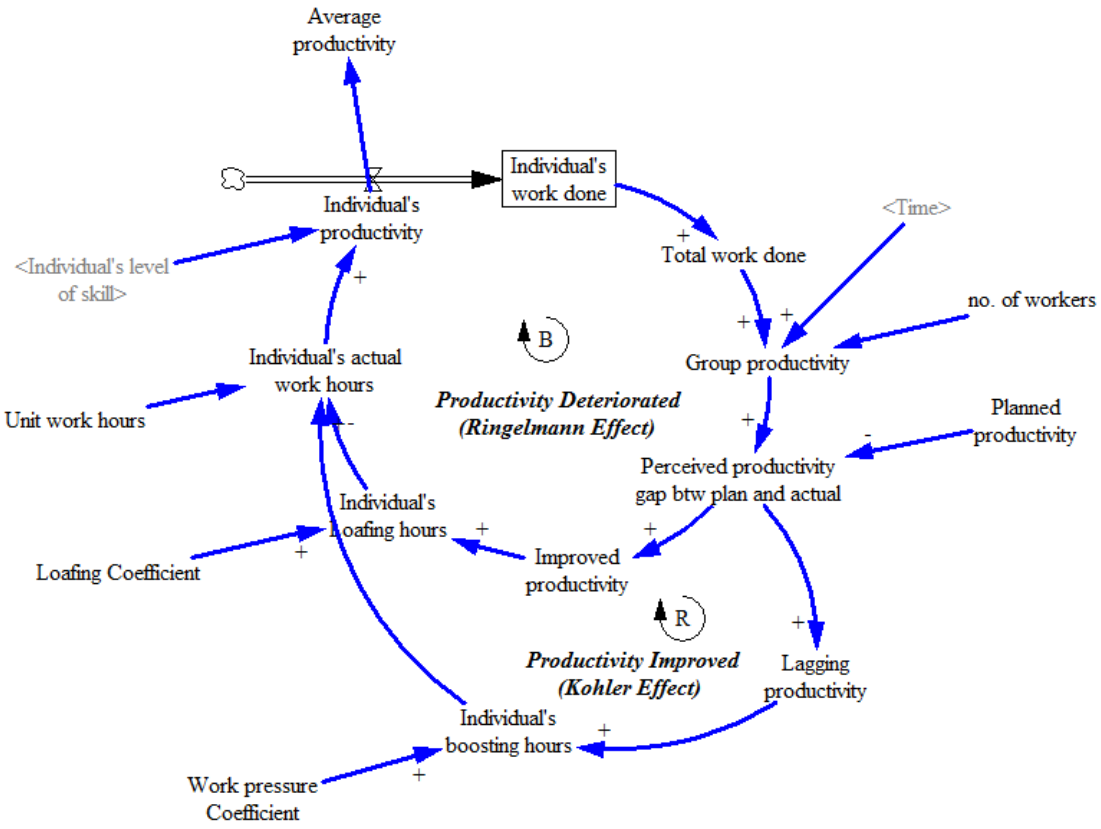

Figure 9. Model for Group Learning Manifestation

Summary

The entire model consists of two processes, group learning development and manifestation process. Learning development and manifestation affect each other and the final result of these processes is 'group productivity'. Group productivity is the only visible variables through the whole process and site managers can control the other invisible variables to improve the group productivity.

With this entire process model, the authors conduct some experiments with scenarios and find partial answers for research questions.

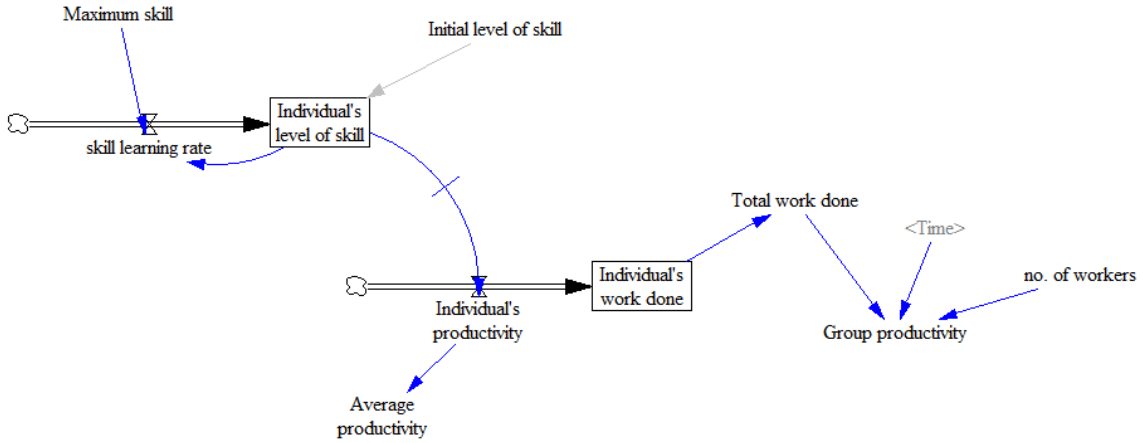

Figure 10. Model for Previous Learning Theory (No Group Effect)

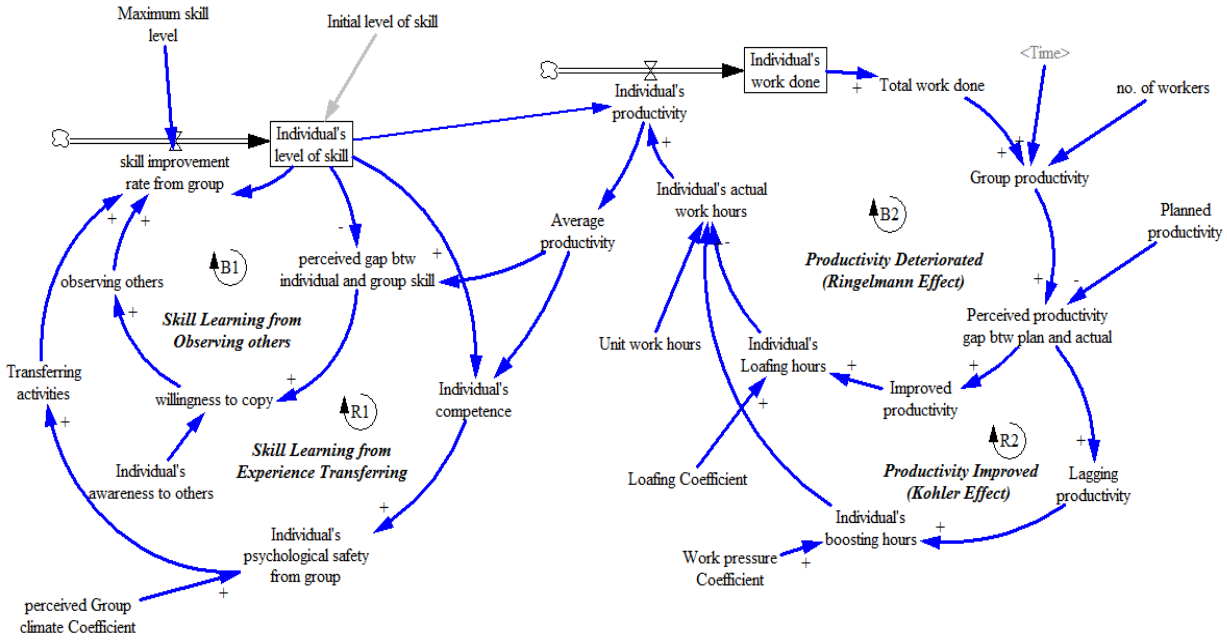

Figure 11. Entire Group Learning Model

Model Analysis

After quantification of the model, the authors build the several scenario cases and conduct the experiments. The model variables are assumed as: Initial Time: 0, Final Time: 300 Days, Time Step: 1 Day, Maximum skill level: 150Q/Day, Planned productivity: 150Q/Day. The laborer's skill and productivity has unit Q/Day, which means the quantities of work done per day (Q means work quantities).

E1) Group Effects Test

E1-1) How the group effect can influence the individual's skill level and group productivity?

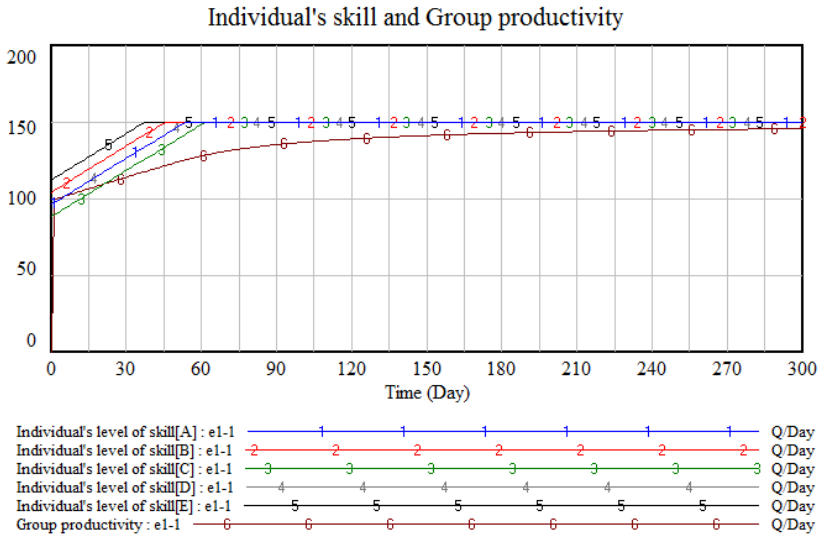

Figure 12. Individual 's Skill and Group Productivity (No Group Effect)

In this experiment, all group members are assumed as skilled laborers (Initial level of skill [A]=96, [B]=104, [C]=88, [D]=96, [E]=112).

Figure 11 shows each group member's skill change and the group productivity, when there is no group effect (using model of Figure 10). In this case, each laborer's skill level increase as much as their skill learning rate which is not considering the individual's characteristics. The authors find that group productivity does not increase as much as their skill level improvement.

E1-2) How the group productivity changes when the group effect exists or not?

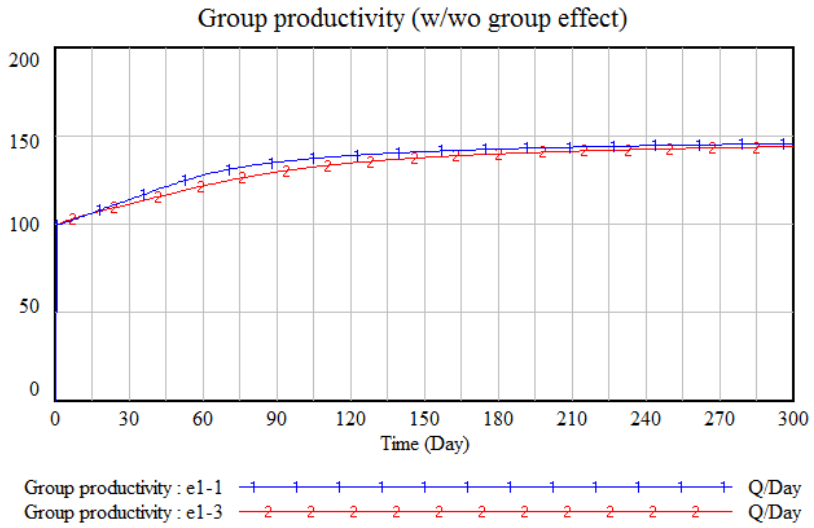

Figure 13. Group Productivity according to the Existence of Group Effect

In this experiment, all group members are assumed as skilled laborers (Initial level of skill [A]=96, [B]=104, [C]=88, [D]=96, [E]=112). The group effect variables are assumed as Table 1.

Table 1. E1-2 Case Scenario

		A	B	C	D	E
Development	Initial level of skill	96	104	88	96	112
	Maximum skill level	150				
	Individual's characteristics to others	0.1	0.1	0.5	0.3	0.7
	Perceived group climate	10	-10	50	30	70
Manifestation	Individual's loafing coefficient	0.1	0.9	0.5	0.9	0.1
	Individual's work pressure coefficient	0.9	0.1	0.5	0.1	0.9
	Planned productivity	150				

Figure 13 shows that group productivity is lower when group effects exist (graph 2). If the group effect variables changes according to the group members' characteristics, the gap between the two curves would also changes (increase or decrease).

E1-3) Is the group productivity same as the average productivity of each individual?

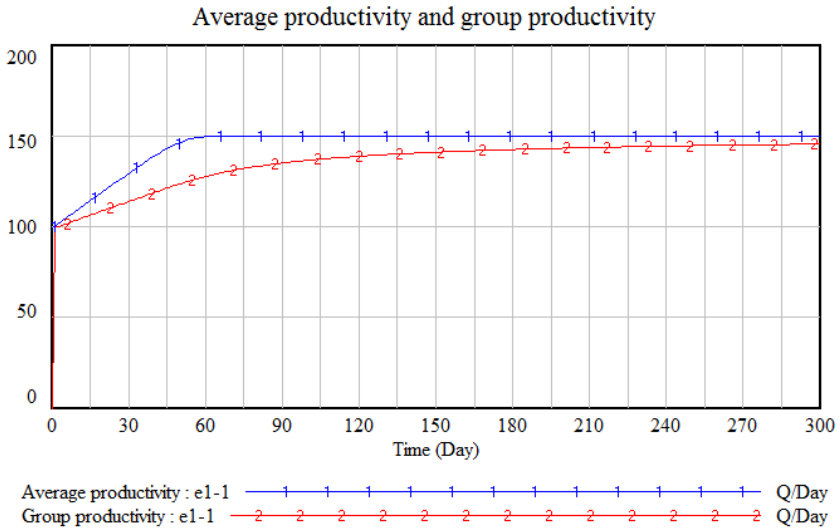

Figure 14. Average Productivity and Group Productivity

In this experiment, all group members are assumed as skilled laborers (Initial level of skill [A]=96, [B]=104, [C]=88, [D]=96, [E]=112). The previous research usually have unstated assumptions that group productivity means the average value of each individual's productivity (i.e., the group productivity is same as the sum of the individual's productivity). However, the Figure 14 shows that the two concepts are clearly different. At early stage of the project, group productivity (graph 2) is much less than the average productivity (graph 1). This result means that project managers should control the group effect especially in early stage.

E2) 'Observing Other's and 'Transferring knowledge' Effect

E2-1) How the individual's observing activities can influence the individual's skill learning?

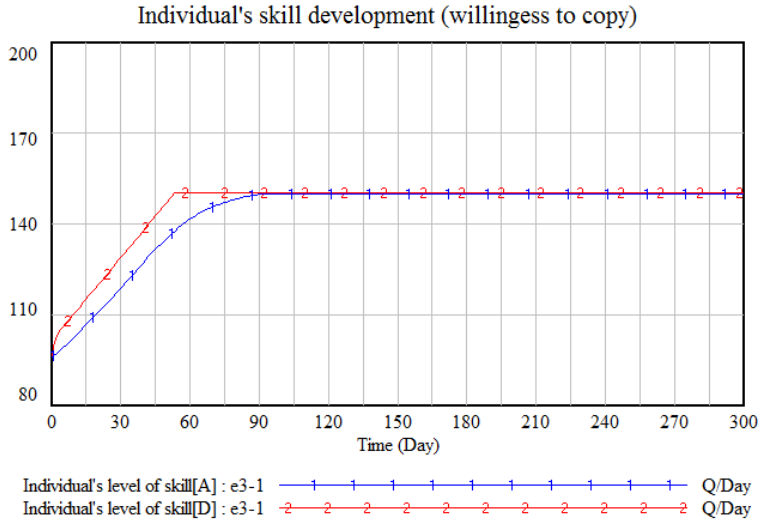

Figure 15. Individual's Skill Development according to Willingness to Copy

In this experiment, all group members are assumed as skilled laborers (Initial level of skill [A]=96, [D]=96). The variable 'Individual's characteristics to others' is assumed as: ([A]=0.1, [D]=0.9).

Figure 15 shows that member [D] (graph 2) who has higher willingness to copy others learns skill faster than member [A] (graph 1).

E2-2) How the individual's perception of the group climate can influence the individual's skill learning?

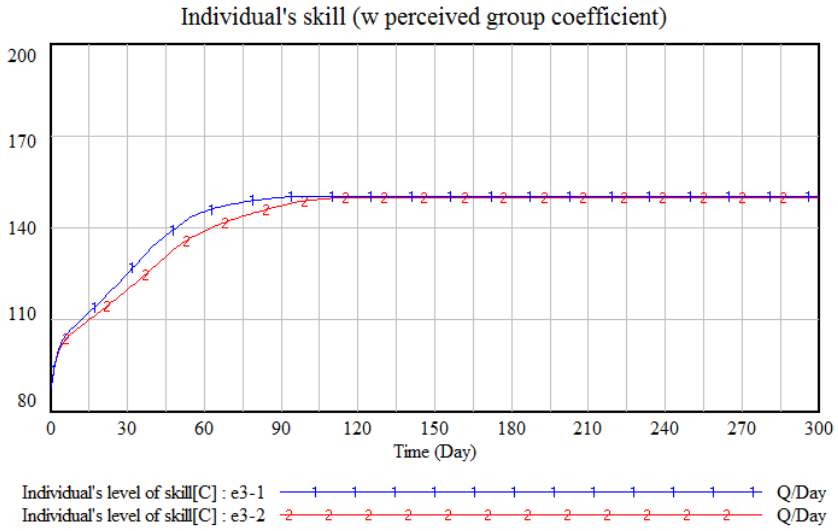

Figure 16. Individual's Skill Development according to Perceived Group Climate

In this experiment, initial level of skill [C] is assumed as 88. The variable 'Perceived group climate' is assumed as 50(graph 1) and -50(graph 2).

Figure 16 shows that a laborer who perceives the group climate as positive learns skill much faster (graph 1) than the negatively perceived (graph 2). This results means that when a laborer perceives the group climate as positive, his/her psychological safety from group increases, and his/her transferring activities are encouraged.

E3) 'Social Loafing' and 'Work Pressure' Effect

E3-1) How the social loafing and work pressure can influence the group productivity?

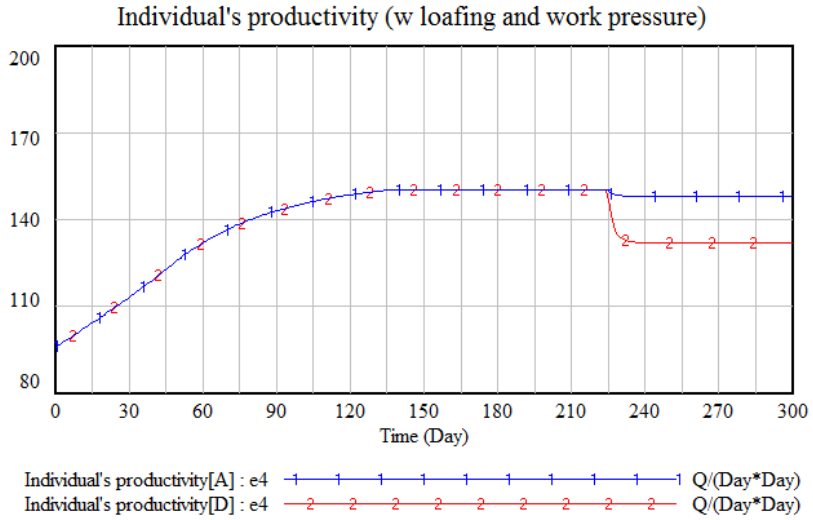

Figure 17. Individual's Productivity according to Social Loafing and Work Pressure

In this experiment, all group members are assumed as skilled laborers (Initial level of skill [A]=96, [D]=96). The variable 'Individual's loafing coefficient' is assumed as: ([A]=0.1, [D]=0.9), and 'Individual's work pressure coefficient' is assumed as: ([A]=0.9, [D]=0.1).

Figure 17 shows that member [D] (graph 2) who tends to work slower after the day when the group achieves the planned productivity (140Q/Day). [D]'s higher loafing coefficient leads his/her productivity reduction when the group performs well (so-called as 'free ride'). According to Figure 18, social loafing effect (graph 2) leads the productivity improvement much slower than the opposite (graph 1).

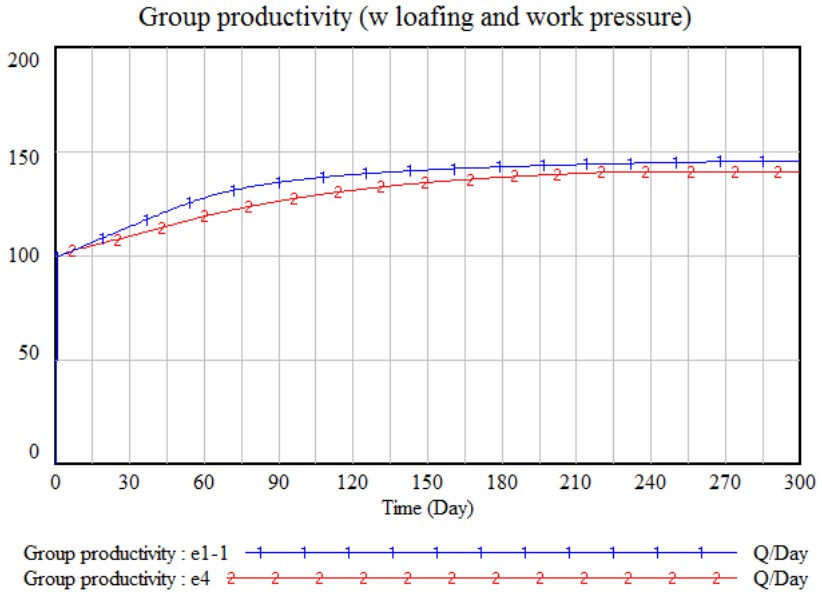

Figure 18. Group Productivity according to Social Loafing and Work Pressure Influences

Results and Discussions

According to results of the three experiments, the authors find that the previous learning theory should be modified when laborers do the tasks in a group. When an individual laborer is aware other members in a group, he/she can adjust the work efforts, not doing best. This phenomenon should be further investigated as a group learning effect.

To improve the laborers' work skill, a manager should reinforce the positive effect of group learning (i.e., encouraging the observing and transferring activities). Also, reducing the social loafing effect is important management strategies to make full use of the laborers' skill and efforts. To find the way of improving the skill learning rate using the group effect and preventing a 'free rider', further experiments should be conducted.

Conclusions

This research analyzes the group learning development and manifestation process in construction tasks. Also, it suggests a conceptual model of labor productivity from laborers' group learning effect with managerial implications.

In future research, the authors should conduct the experiments, which includes the construction tasks' characteristics. At the same time, laborers' actual observing, transferring, and monitoring activities will be investigated with a survey and interview, to validate the model. However, the authors also presume that developed model cannot calculate the exact value of labor productivity and its result will be limited to forecast relative magnitude and trends.

The authors expect that this research will extend the previous research of 'learning in construction' to more practical level. It contributes to explaining an invisible phenomenon through visible model. Also, it would finally be helpful for maximizing laborers' productivity in construction sites.

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