evaluation (with a perfect score of 40) from the audiences. The individual presentation score was the mean score given by the audiences. Finally, every student had to make a report (with a perfect score of 5) about this presentation event to describe what they learned from other presenters and how can they improve their own group design. In summary, each student had three individual performance indexes: one for the contribution in group work, another for the presentation, and the other for final report. Two major research questions are discussed based on the analysis of learner data involving these three indexes.

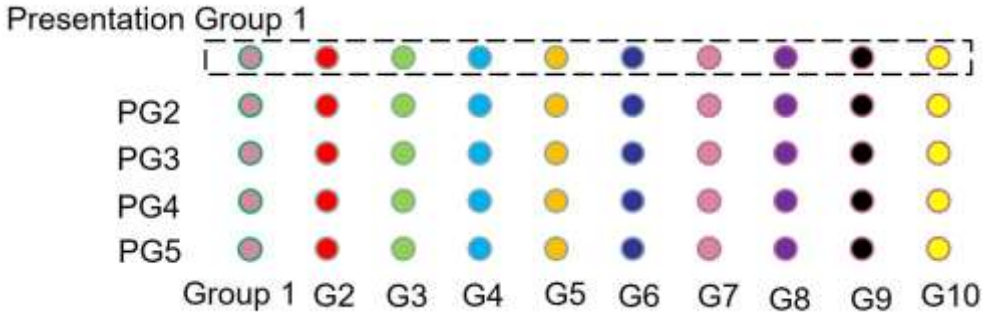

Figure 2: A group distribution example of a class with 50 students

3.1 Direct Factors of Individual Performance

The first research question concerns how the learner attributes (including the motivation and learning strategy scales, and learning style scales) were related to individual performance in the cooperative course. Table 2 displays the result of the correlation analysis among the rankings of motivation, learning strategy variables, learning styles, and the individual performance.

Table 2: The correlation among learner attributes and individual performance

Performance / Attributes		Score for group work	Presentation	Report
	Mean	44.94	32.03	3.88
	SD	8.41	2.63	0.93
Belief	Self-efficacy	0.226**	0.254**	0.131
	Intrinsic value	0.247**	0.128	-0.015
Learning strategy	Retrieval strategy	0.114	0.053	0.099
	Assimilation and effort management strategy	0.200**	0.069	0.119
Learning styles	Active	0.064	0.247**	-0.088
	Sensing	0.041	0.007	0.271**
	Visual	-0.025	0.116	0.000
	Sequential	-0.03	-0.003	0.113

**p< .01, N=157.

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Although the three performance measures were not significantly correlated with each other (presentation score and score for group work: r=0.131, presentation score and report score: r=0.037), the score for group work and presentation score are slightly correlated (r=0.155, p=0.056). The discussion about which factors directly affect these three performances are as follows.

(1) As shown in Table 2, higher individual score for group work were associated with higher levels of perceived self-efficacy, intrinsic value and the use of assimilation strategy and effort management. A regression analysis (R = 0.247) reveals that individual score for group work were directly positively related to perceived intrinsic value only. This suggests that the higher intrinsic value of the course a learner perceived, the better performance she/he had in group work.

(2) Higher individual presentation score was only associated with higher levels of self-efficacy and higher level of active learning style. Regression analysis of individual presentation (R = 0.324) reveals that individual presentation score was directly positively related to both self-efficacy and active dimension of learning style. This suggests that the higher self-efficacy a learner perceived, the better performance she/he may get in the presentation task and the stronger active preferences identified by ILS a learner had, the better performance she/he may had in the presentation task.

(3) Higher individual report score was only associated with higher level of sensing learning style. This suggests that the stronger sensing preferences identified by ILS a learner had, the better performance she/he may had in the task which requiring describing what she/he learn from other presenters and how to improve her/his own group work.

3.2 Gender Differences in Learning Performance

The second research question concerns if the gender differences affected the learning individual performance in the cooperative course. Table 3 displays the t-test results of the learning performance of the male and female students. There were significant gender differences in the individual score for group work and in the score of individual report, but no in the presentation score. This suggests that compared to male students, the female students may have a better performance on group work and on assignments that require reflection although they do not differ on the presentation performance.

Table 3: The ANOVA result of gender differences in individual learning performance

	Gender	N	Mean	SD	Levene's Test	ANOVA
Score for	male	101	43.95	8.97	sig=0.278	F= 4.093*
group work	female	56	46.75	6.99		Sig= 0.045
Presentation	male	98	31.89	2.81	sig=0.187	F= 0.701
	female	55	32.27	2.26		Sig=0.404
report	male	98	3.76	0.93	sig=0.938	F= 4.662*
	female	55	4.09	0.91		Sig= 0.032

*p< .05

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4 Predict Group Performance and its Application to the Group Formation Problem

4.1 Formulations for Predicting Group Performance

In literature, the goodness of group formation is normally defined based on the heterogeneity or homogeneity of group members' attributes [10] [14] [15]. Davidson [35] claims when a task requires the group members to working on a specific skill, procedure or set of facts, homogeneous groups can enable instructors to address the problems of learners according to their ability level; when a task requires the group members to working on open-ended problems and learn how to communicate, heterogeneous groups can encourage learners with different abilities to contribute for potential solutions without caring about their ability because of the exiting of more than one correct answer. Since the tasks given in the target course in this study are open-ended problems and the goal of target course is encouraging the development of communication skill, the relation between group performance and the heterogeneity of group members' attributes is examined.

To obtain heterogeneous groups, Graf and Bekele [10] had proposed a math model considering the mean, minimum and maximum of all the learner attributes as group variables. In this paper we propose to only take into account the learner attributes, which directly related to learning performances according to the learning analysis results, for the further calculation of group variables. Since the group formation approach considering too many learners attributes will drastically increase computation time, making use of learning analytic technique, the attributes, which directly related to learning performance, could be identified; analysis results can exclude uncorrelated attributes and reduce the amount of the attributes in the calculation of grouping formation. In other word, if the scores of each group could be predicted based on some attributes of the group members, in practical the group learning performance could be enhanced by adjusting the grouping.

According to Table 2, perceived self-efficacy, intrinsic value, the use of assimilation strategy and effort management, and the levels of active and sensing learning styles, these five learner attributes should be use for further group variables calculation due to their significant correlation with learning performance. Table 4 shows the correlation between those group variables and group performance (5 or 6 students per groups, 28 group in total). The use of retrieval strategy, visual and sequential learning styles are not considered here for the calculation of group variables since these three attributes were uncorrelated with any individual learning performance in this cooperative course as described in Table2.

Table 4: The Pearson correlation between group variables and group performance

	Self-Efficacy	Intrinsic Value	Assimilation and effort management	Active	Sensing
M	0.147	0.585**	0.322	0.100	0.009
Min	0.632**	0.406**	0.118	-0.007	0.043
Max	0.490**	0.531**	0.312	0.365	0.239

**p< .01 and N=28.

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Assumed the amount of each class is N and learners $\{L_1, L_2,\ldots, L_N\}$ are supposed to be distributed into M groups $G_1, G_2,\ldots, G_M$, then the member amount of each group K=N/M. According to conclusion of the second research question, female students had significantly better learning performance in group working. The percentage of female member in a group is also considered. In summary, the percentage of female member and the 15 group variables in Table 4 are considered in a regression analysis on group performances (the sum of group total report scores).

The stepwise regression result (R=0.824, R square=0.679, Adjusted R square=0.623) suggests the following formulation for prediction of the group performance (the predicted scores of group Gi is S (Gi)):

$$S(G_i) = 12.079 + 4.284\text{Min}(\text{Self-Efficacy}[G_i]) + 8.023\text{M}(\text{IntrinsicValue}[G_i]) - 3.384\text{Min}(\text{AssimilationStrategy}[G_i]) - 1.406\text{Min}(\text{Active}[G_i]) \quad (1)$$

where M (A[Gi]), Min (A[Gi]), and Max (A[Gi]) represent the mean, minimum, and maximum values of the attribute A for group Gi.

By contrast, the backward regression result (R=0.893, R square=0.798, Adjusted R square=0.727) suggests the following formulation for prediction of the group performance:

$$S(G_i) = -23.502 + 3.952\text{Min}(\text{Self-Efficacy}[G_i]) + 2.677\text{Min}(\text{IntrinsicValue}[G_i]) + 3.094\text{Max}(\text{IntrinsicValue}[G_i]) + 10.744\text{M}(\text{AssimilationStrategy}[G_i]) - 3.384\text{Min}(\text{AssimilationStrategy}[G_i]) - 2.240\text{Min}(\text{Active}[G_i]) + 1.650\text{Max}(\text{Sensing}[G_i]) \quad (2)$$

Although there may be other factors that affect the group performance, the regression model suggested by formula 1, can be used to explain 62.3% of the observed group performance data; while the regression model suggested by formula 2, can be used to explain 72.7% of the observed group performance data. Formula 1 and formula 2 both involve three group variables: Min(Self-Efficacy[G_i]) and Min(AssimilationStrategy[G_i]) and Min(Active[G_i]). Formula 2 with higher R value requires the calculation on 5 attributes of group members (7 variables in total); besides the 4 attributes (self-efficacy, intrinsic value assimilation strategy and effort management strategy, and active learning style) of group members required in the calculation of formula 1 (4 variables in total), each group member's learning style indicator in sensing dimension is also required in formula 2.

In future, more analysis will be conducted on learner data for other subtopic of this course to explore the robustness of these two formulas. Finally, the one with higher robustness will be determined for the model presented next. No matter which formula is determined, requiring the calculation on 4 or 5 learner attributes, sharply decreases the workload compared to considering all the 8 attributes described in table 2.

4.2 An Adjustable Model to Find Optimum Solution of Group Formation

As discussed in the introduction, when multiple attributes of learners are considered, identifying good ones among vast grouping candidates generally becomes complicated. This group formation problem is often regarded as an optimization problem with discrete variables. Typical

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approach is exploring the optimum of the grouping solution through maximization of an objective function that measures the goodness of a group formation [7] [8] [9] [10] [11]. Along this approach, in our study, we can construct the objective function in response to teaching strategies by using the prediction formula for group performance as follows.

(1) If the teaching goal is to pursuit maximizing the average value of all the groups' score, then $S_{mean} = \Sigma_i S(G_i)/M$ is regarded as the objective function of the group formation. The optimum solution of the group formation could be done if the grouping whose attributes maximize of Smean can be found.

(2) If the teaching goal is to pursuit the homogeneous of all the groups' scores, then $S_{Var} = \Sigma_i (S(G_i) - S_{mean})2/M$ is suitable for the objective function of the group formation. The optimum solution of group formation could be done if the grouping whose attributes minimize S_{Var} is found.

(3) If the teaching goal is to pursuit both the average value maximization and the homogeneous of all the groups' scores, then the objective function can be considered as the following mixed type function:

$$S_{mix} = c1 * S_{mean} - c2 * S_{Var}.$$

Here c1 and c2 are positive coefficients, which should be set as suitable values. The optimum solution of the group formation could be done if the grouping whose attributes maximize Smix can be found.

The next step of the study is to develop a tool that implements an adjustable mathematical model, which allow the instructor to determine one of the teaching strategies mentioned above. A series of experiment will be conducted to compare the model under three proposed teaching strategies using real-world data. The performance effectiveness and robustness are expected to be evaluated.

5 Conclusion

In this paper, based on the analysis of learner characteristics measured in the real-world, the prediction of group performance for the group formation is formulated. Firstly, it is found that perceived self-efficacy, intrinsic value, the use of assimilation strategy and effort management, and the levels of active and sensing learning styles, these five learner attributes are related to the individual performances in the cooperative course. Secondly, the results of further (stepwise and backward) regression analysis on group learning performance suggest two formulas for predicting the group performance. Further analysis work on learner data collected from other topics of this course will be conducted to explore the robustness of these two formulas for predicting group performance. Finally, using the prediction formula with better robustness, we present mathematical models for forming groups of learners under different teaching strategies. To sum up, for the evaluation of the goodness of a group formation, the objective function adopts the formulation suggested by real-world data analysis results to predict the group scores.

The limitation of this study is that the analyses only focus on the relation between group performance and four aspects of member attributes (learning motivation, learning strategy,

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learning style and gender) due to the specific goal of the target course which requires group members working on open-end problem-solving tasks. Although the Adjusted R-squared of the formulas 1 and 2 suggests that the majority of the group performance variance (more than 60%) can be predicted. However, human learning behaviors are complicated, and these may be other factors that affect the group performance. Further learner data should be collected and analyzed to explore the robustness of these two formulas.

In the future, we will implement a tool based on an adjustable mathematical model to support daily teaching of "Interdisciplinary collaborative learning of Social Issues" course. One input of this tool is the learner characteristics (learning motivation, learning strategy and learning style) data which should be collected before the grouping. Another input of the tool is the teaching strategy (pursuit maximizing the average value of all the groups' score, pursuit the homogeneous of all the groups' scores, or pursuit both the average value maximization and the homogeneous of all the groups' scores) which needs to be determined by the instructor. With these two inputs, the tool making use of the formula predicted by this study, will automatically suggest the grouping candidates to maximize the learning outcome in response to the teaching strategy. A series of experiments will be conducted to study the effectiveness of this tool.

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References

[1] J. E. Camara, B. N. Carr, & B. L. Grota, "One approach to formulating and evaluating student work groups in legal environment of business courses," Journal of Legal Studies Education, 24(1), 2007, pp.1-18.

[2] D. H. Jonassen, & H. I. Kwon, "Communication patterns in computer-mediated and face-to-face group problem-solving," Educational Technology Research and Development, 49(1), 2001, pp. 35–51.

[3] J. I. Tutty, & J. D. Klein, "Computer-mediated instruction: a comparison of online and face-to-face collaboration," Educational Technology Research and Development, 56(2), 2008, pp.101-124.

[4] P. H. Miller, "Vygotsky's theory and the contextualists", Theories of developmental psychology, R. C. Atkinson, G. Lindzey, & R. F. Thompson, eds., New York: W. H. Freeman and Company, 1993, pp. 368-423.

[5] M. Huxland, & R. Land, "Assigning students in group work projects: can we do better than random?" Innovations in Education and Training International, 37 (1), 2000, pp.17-22.

[6] J. W. Li, Y. T. Wang, & Y. C. Chang, "The Differences between Self-Organized Group and Designated Group for Cooperative Learning," 7th International Conference on Ubi-Media Computing and Workshops, 2014, DOI: 10.1109/U-MEDIA.2014.63.

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[7] G.J. Hwang, P.Y. Yin, C.W. Hwang, & C.C. Tsai, "An Enhanced Genetic Approach to Composing Cooperative Learning Groups for Multiple Grouping Criteria," Journal of Educational Technology & Society, 11(1), 2008, pp.148-167.

[8] J. Moreno, D.A. Ovalle, and R.M. Viccari, "A genetic algorithm approach for group formation in collaborative learning considering multiple student characteristics," Computers and Education, 58, 2012, pp. 560–569.

[9] W.M. Cruz, S. Isotani, "Group Formation Algorithms in Collaborative Learning Contexts: A Systematic Mapping of the Literature", Collaboration and Technology, LNCS 8658, N. Baloian, F. Burstein, H. Ogata, F. Santoro, G. Zurita, eds., Springer, Cham, 2014, pp.199-214.

[10] S. Graf, and R. Bekele, "Forming Heterogeneous Groups for Intelligent Collaborative Learning Systems with Ant Colony Optimization", Intelligent Tutoring Systems, LNCS 4053, M. Ikeda, K.D. Ashley, T.-W. Chan, eds., Springer, Heidelberg, 2006, pp.217-226.

[11] Y.-T. Lin, Y.-M. Huang, S.-C. Cheng, "An automatic group composition system for composing collaborative learning groups using enhanced particle swarm optimization," Computers & Education, 55 (4), 2010, pp.1483-1493.

[12] C.-C. Liu, and C.-C. Tsai, "An analysis of peer interaction patterns as discoursed by on-line small group problem-solving activity," Computers & Education, 50 (3), 2008, pp.627-639.

[13] Y. Taniguchi, Y. Gao, K. Kojima, S. Konomi, "Evaluating Learning Style-Based Grouping Strategies in Real-World Collaborative Learning Environment,". Distributed, Ambient and Pervasive Interactions: Technologies and Contexts (DAPI 2018), LNCS 10922, N. Streitz, S. Konomi, eds., Springer, Cham, 2018, pp. 227-239.

[14] S. Allan, "Grouping and the gifted ability-grouping research reviews: What do they say about grouping and the gifted? "Educational Leadership, 48(6), 1991, pp.60-65.

[15] S. B. Watson, & J. E. Marshall, "Effects of cooperative incentives and heterogeneous arrangement on achievement and Interaction of cooperative learning groups in a college life science course," Journal of Research in Science Teaching, 32(3), 1995, pp.291-299.

[16] H. W. Marsh, "The big-fish-little-pond effect of academic self-concept," Journal of Educational Psychology, 79, 1987, pp. 280-295.

[17] N. M. Schullery, & S. E. Schullery, "Are heterogeneous or homogeneous groups more beneficial to students? Journal of Management Education," 30(4), 2006, pp. 542-556.

[18] K. Welner, & R. Mickelson, "School reform, politics and tracking: Should we pursue virtue?" Educational Researcher, 29(4), 2000, pp. 22-26.

[19] M. Scherer, "On savage inequalities: A conversation with Jonathan Kozol," Educational Leadership, 50, 1993, pp. 4-9.

[20] M. Guralnick, "A hierarchical model of understanding children's peer-related social competence,". Social competence of young childrenwith disabilities: Issues and strategies for intervention, S.L. Odom, S.R. McConnell & M.A. McEvoy, eds., Baltimore: Paul H.

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Brookes, 1992, pp. 37-64.

[21] T. Pica, & C. Doughty, "The role of group work in classroom second language acquisition," Studies in Second Language Acquisition, 7, 1985. pp. 233-246.

[22] P. Porter, "How learners talk to each other: Input and interaction in task-centered discussions," Talking to learn: Conversation in second language acquisition, R. Day ed., Rowley, MA: Newbury House, 1986.

[23] S. Cotterall, "Developing reading strategies through small-group interaction," RELC Journal, 21, 1990, 55-69.

[24] R. R. Pintrich, and E. V. DeGroot, "Motivational and self-regulated learning components of classroom academic performance," J. Educational Psychology, 82, 1990, pp. 33-40.

[25] F. Coffield, D. Moseley, E. Hall, and K. Ecclestone, Learning styles and pedagogy in post-16 learning: A systematic and critical review, London: Learning and Skills Research Centre, 2004.

[26] H. Pashler, M. McDaniel, D. Rohrer, and R. Bjork, "Learning styles: Concepts and evidence," Psychological Science in the Public Interest, 9(3), 2009, pp. 105–119.

[27] R.M. Felder and E.R. Henriques, "Learning and Teaching Styles in Foreign and Second Language Education. Foreign Language Annals," 28 (1), 1995, pp. 21–31.

[28] R.M. Felder and J.E. Spurlin, "Applications, Reliability, and Validity of the Index of Learning Styles," Intl. Journal of Engineering Education, 21(1), 2005, pp.103-112.

[29] J.Y. Wang, & T. Mendori, "The Reliability and Validity of Felder- Silverman Index of Learning Styles in Mandarin Version," Information Engineering Express, 1(3), 2015, pp. 1-8.

[30] G. A. Livesay, K. C. Dee, E. A. Nauman and L. S., Jr. Hites, "Engineering student learning styles: a Statistical Analysis Using Felder's Index of Learning Styles," Conference of the American society for engineering education 2002, Montreal, Quebec, 2002.

[31] N. V. Zwanenberg, L J. Wilkinson, & A. Anderson, "Felder and Silverman's Index of Learning Styles and Honey and Mumford's Learning Styles Questionnaire: How do they compare and do they predict academic performance?" Educational Psychology, 20 (3), 2000, pp. 365-381.

[32] M.S. Zywno, "A Contribution to Validation of Score Meaning for Felder Soloman's Index of Learning Styles," Proceedings of the 2003 ASEE Annual Conference, ASEE, 2003.

[33] B.W. Tuckman, Conducting Educational Research, 5th edition, Belmont, CA: Wadsworth Group, 1999.

[34] E. Aronson, and S. Patnoe, "The jigsaw classroom: building cooperation in the classroom," 2nd edn, Addison Wesley Longman, New York, 1997.

[35] N. Davidson, Cooperative Learning in Mathematics: A Handbook for Teachers, Menlo Park, CA: Addison-Wesley, 1990.

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