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On the Efficacy of Student Teams in Engineering:

An Assessment of Individual Learning in Collaborative Projects

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Systems Engineering is a team sport

- Large scale engineering is a 'team sport' so it makes sense to train engineers in them. So,
  - Academic programs frequently use team projects.
    - One study found that 24% of engineering instructors always assigned group projects and 52% assigned them in some courses[1].
    - ABET includes functioning within a multidisciplinary team as one of their 11 program outcomes.
  - Engineering Development programs are frequently team focused.
- But, students often resent working in teams[2].
  - Frustrated with little influence and no control over their team-mates;
  - Belief that their grade will not reflect their contribution or competence;
  - That the transaction cost of scheduling meetings, and working collaboratively are not worth the rewards, of which they see few.
- This raises several important questions:
  - Do students learn how to effectively function as a team simply by working on team projects?
  - Should students be given classes, training, or guidance on how to be a team player?
  - Does the act of working in a team benefit or hinder a student's learning of course content?

In short, do engineers working in teams become more proficient engineers AS WELL AS better team members?

The Impact of Teams on Learning

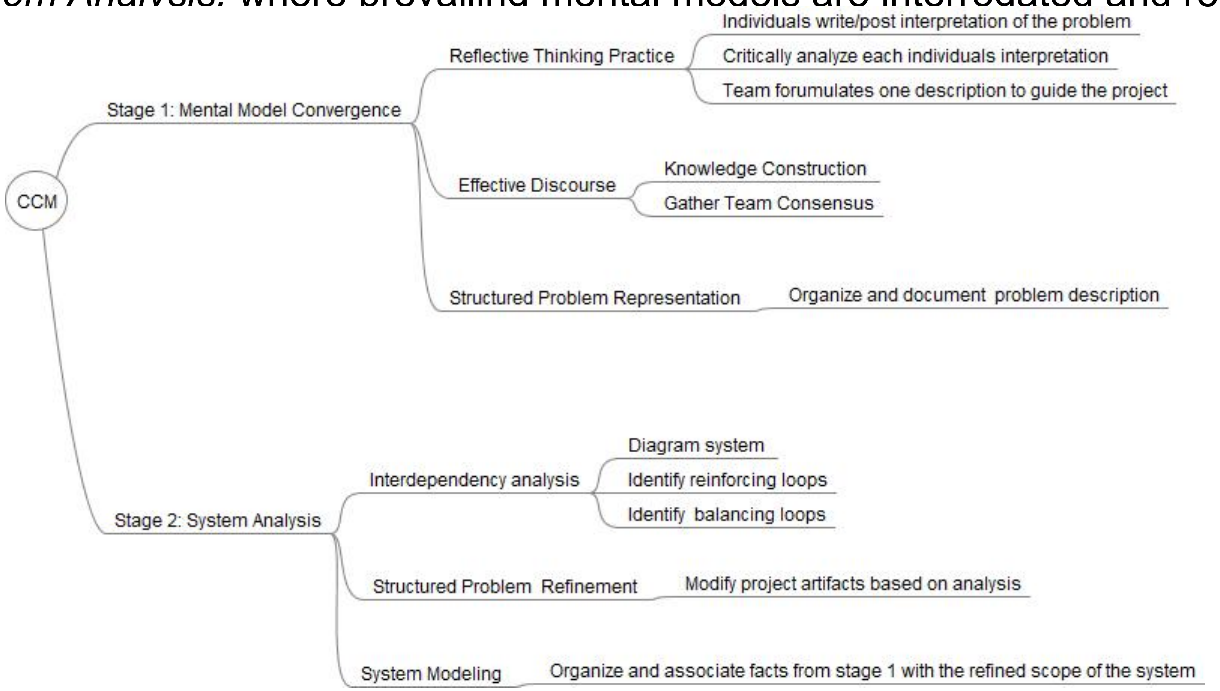
- There is little consensus on the efficacy of student teams.
- On the one hand:
  - Students benefit from working in teams through social construction[3, 4] .
  - Through peer interaction and collaboration student's are able to synthesize and evaluate their ideas collectively[5].
- But:
  - Bad team experiences can sour students on teamwork far beyond their education studies and in to the workplace[6].
  - The tendency for student teams to work cooperatively rather than collaboratively can severely impact learning[7].

Effective teams need guidance

- Cooperative teamworking (where the total work is divided across the teams) is often the default strategy.
  - It assumes that the correctness of a subsystem is intrinsic – it isn't!
  - Role specialization means that each individual experiences only a portion of the development process or the developed system.
  - Might be the preferred approach of those drawn to the engineering disciplines[7].
- Collaborative teamworking (where the team works together on a single shared goal) requires more time and effort.
  - Team members experience all aspects of the development process and the system.
  - Coordination and governance are more demanding
  - Social construction aids student learning.

A guidance model for team collaboration

- We have developed a framework of individual and team activities designed to facilitate effective collaborations.
- Previously shown that the model is effective and that it results in greater convergence of shared mental models in teams[9,10,11].
- Model consists of 2 stages.
  - *Mental Model Convergence,* which deals with surfacing tacit assumptions.
  - *System Analysis,* where prevailing mental models are interrogated and refined.



Hypotheses

- The goal of this research was to investigate the full extent of the efficacy of the collaboration model in improving the outcomes of teams and individuals.
- In previous publications we have shown support of the following 3 hypotheses:
  - *H1. Use of the CCM by team members will improve the project outcomes for that team.*
  - *H2. Use of the CCM will facilitate the forming of a team mental model.*
  - *H3. Use of the CCM will facilitate team learning.*
- In this experiment, we tested a 4th hypothesis:
  - *H4: An individual's learning is improved when working on an effective team*.

Our experiment

- Subjects were graduate engineering students working in teams of 4 or 5.
- This experiment was conducted using three sections of an online graduate course in architecture and design.
- One section was the control group (n=18) and the other two sections (n=21 and n=18) were the treatment groups with access to the collaboration model.
- Pre- and post-testing employed to determine the degree of individual learning using identical assessments.
  - Pre-test – benchmark test designed to assess prior knowledge of course content
  - Post-test – course exam designed to assess course learning objectives
- All tests were graded, independently of course assessment, by the section facilitators.

Inter-rater reliability

- Since the analysis involves the averages of the judge's scores, we must test the inter-rater reliability.

Group	Test	Judge	Mean	Std Dev.	T	p=
Control	Pre	1	26.9	16.5	-3.02	**0.005**
		3	46.7	22.4		
	Post	1	76.5	14.9	-.09	0.929
		3	76.9	11.8		
CCM Condition 1	Pre	1	26.3	13.8	-3.84	**0.0**
		2	44.5	16.7		
	Post	1	73.7	16	-0.93	0.357
		2	78.7	18.8		
CCM Condition 2	Pre	2	46.4	18.2	0.45	0.653
		3	43.8	16.1		
	Post	2	90.42	6.52	-0.24	0.811
		3	90.94	6.54		

- Judge 1 (me!) shows significant difference in evaluating the pre-test versus Judges 2 and 3.

Team results

- The teams were assessed via the work products submitted at each checkpoint as well as their final project report.

Assignment	With CCM	No CCM	Statistic
Use case analysis	Mean = 87.5 σ = 4.4	Mean = 82.9 σ = 6.96	T = -1.98 **P = 0.03**
Domain modeling	Mean = 88.3 σ = 5.18	Mean = 86.4 σ = 6.69	T = -0.82 P = 0.22
Interaction modeling	Mean = 87.2 σ = 5.97	Mean = 84 σ = 3.72	T = -1.58 P = 0.07
Design	Mean = 87.6 σ = 4.98	Mean = 80.7 σ = 6.33	T = -3.04 **P = 0.003**
Project	Mean = 94.8 σ = 2.6	Mean = 81.1 σ = 6.93	T = -6.62 **P = 0.00**
Overall	Mean = 88.7 σ = 2.33	Mean = 82.5 σ = 3.92	T = -4.8 **P = 0.00**

- On average following the guidance of the collaboration model saw improved checkpoints and project scores. Team outcomes are improved.

Pre- vs Post-test results

- The results reveal that:
  - Judge 1 found that the control group marginally outperformed CCM 1;
  - Judge 3 found that CCM 2 significantly outperformed the control group, and
  - Judge 2 found that CCM 2 outperformed CCM 1 but not significantly.

Judge	P value	Control (n=18)	CCM 1 (n=21)		CCM 2 (n=18)
1	.698	$\mu = 49.6$ $\sigma = 18.8$	$\mu = 47.3$ $\sigma = 15.9$		No Judging
2	.117	No Judging	$\mu = 34.2$ $\sigma = 20.0$		$\mu = 44.1$ $\sigma = 18.3$
3	**<u>.022</u>**	$\mu = 30.2$ $\sigma = 25.3$	No Judging		$\mu = 47.2$ $\sigma = 15.8$
Averages	Control Average vs. CCM 1 Average p=. 884	$\mu = 39.9$ $\sigma = 21.1$	$\mu = 40.8$ $\sigma = 17.1$	Control Average vs. CCM 2 Average p= .366	$\mu = 45.6$ $\sigma = 16.4$

Analysis

- The overall average of all judges was also not significant and thus the hypothesis that use of the collaboration model, and therefore effective teamwork, will facilitate improved individual learning is **not confirmed**.
- So, improved project outcomes do not correlate to improved individual learning.

Potentially broad implications

- Team projects and team assessment are frequently used in engineering programs, but do they:
  A. Facilitate learning at the individual level?
  B. Accurately discriminate the understanding and knowledge of the individual?
- Team-based approaches to personnel development programs also often confound team learning and team outcomes with individual improvement.

Future directions

- We are already working on addressing the concerns raised by this study
  - COIL funded grant to investigate student experiences in teams
  - Qualitative study using constant comparison of survey and interview responses
  - Evidence-based, theoretically-supported refinements to the collaboration model to address the disconnect between team and individual learning.

References

1. Felder, R.M., Brent, R., Miller, T.K., Brawner, C.E. and Allen, R.H. Faculty teaching practices and perceptions of institutional attitudes toward teaching at eight engineering schools, *Proc. 1998 FIE Conf.*, Tempe, AZ, 1998.
2. Caspersz, D.M., Wu, M., Skene, J. Factors Influencing Effective Performance of University Student Teams, in *Proc. 26th Annual International HERDSA Conf.*, Christchurch, NZ.
3. Hilborn, R.B. Team learning for engineering students, *IEEE Trans. Educ.*, vol. 37, no. 2, 1994, pp. 207–211.
4. Johnson, D.W., Johnson R.T., and Smith, K.A. Cooperative Learning: Increasing College Faculty Instructional Productivity: ASHEERIC Higher Education Report No. 4. Washington, D.C.: The George Washington University, School of Education and Human Development, 1991.
5. Corden, R.E. (2001). Group discussion and the importance of a shared perspective: Learning from collaborative research. *Qualitative Research*, 1(3), 347-367.
6. Buckenmeyer, J.A. Using teams for class activities: Making course/classroom teams work, *Journal of Education for Business*, Vol. 76, No. 2, Nov. 2000, pp. 98-108.
7. Greco E. and Reasoner, J. Student Laboratory Skills and Knowledge Improved through Individual Lab Participation, *Proc. ASEE Annual Conference*, Lousiville, KY, June 2010.
8. Witkin, H.A., Goodenough, D.R., 1977. “Field Dependence and Interpersonal Behavior,” *Psychological Bulletin*, 84 (4); 661-689.
9. DeFranco, J.F., Neill, C.J. Improving Learning Outcomes using Cognitive Models in Systems Design, *Proc. ASEE Annual Conf*, Austin, TX, June 2009.
10. DeFranco, J.F., Neill, C.J. Improving Team Performance: The Cognitive Style Factor, *Proc. ASEE Annual Conf*, Louisville, KY, June 2010.
11. DeFranco, J.F., Neill, C.J., Clariana, R.B. A Cognitive Collaborative Model To Improve Performance in Engineering Teams – A Study of Team Outcomes and Mental Model Sharing, to appear *Systems Engineering Journal*, Vol. 14, No 3, 2011.