Exploring Collaborative Modeling as Teaching Method
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Abstract
Group Model Building (GMB) often refers to collaborative system dynamics (SD) modeling. Despite its impressive success in various interdisciplinary domains, SD still struggles to be adopted as a mainstream method in the very areas where it has proven its worth. SD is hard to learn, and acquiring modeling skills can take long time. SD is mostly taught in modeling courses with examples from various disciplines, in a non-collaborative way.

Learning SD modeling as a “byproduct” in courses (like ICT, security, industrial management) and in collaborative way would seem at the outset a losing proposition. Experiences with an approach using a project-oriented approach adapting ideas and exercises from GMB suggests otherwise: Students consistently perform well, with marked learning curves in SD modeling, course matters, and project execution skills. Student satisfaction is high in most respects. Some students, though, report that they spend more hours in coursework than they had expected.

1. Introduction
The term Group Model Building (GMB) refers to facilitated workshops to elicit model structure and give problem owners / clients an active role in dynamics model conceptualization, formulation, analysis and policy design. GMB has a long story, dating back to early attempts in 1978 to involve clients in the model building process [1]. In the 1990’s a series of papers [2-6], book chapters [7] and a book [8] made GMB well-known. A 2002 review of 107 cases using GMB [9] provided “preliminary insights” on the effectiveness of GMB. Interestingly, authors did have a strong conclusion: “learning about the problem seemed to be a robust outcome of GMB.”

The author of this paper has accumulated experience in GMB through various projects dealing with security, safety and Critical Infrastructure Protection / Homeland Security [10-13]. Evaluations using questionnaires seem to confirm that learning and insight about the problem in question indeed are a robust outcome of GMB.

Thus the question arises: Could GMB be used – properly adapted – as a method to improve learning of SD? To help address the question we provide preliminary insights derived from our using GMB in system dynamics courses. This research study paper is a byproduct of our teaching experiences, and as such we will continue the study along with teaching courses in the future. The method of inquiry is qualitative, based on reports and notes from a ten year period. Since the teaching methods have been evolving during this period, consistent quantitative evidence cannot be derived from this period’s data, owing to the resulting changes in the approach. Nevertheless, we hope that our qualitative and preliminary insights could lead to constructive criticism, and possibly interest colleagues to try the approach and, whether by falsifying or failing to do so, to establish a solid scientific basis for collaborative modeling’s worth as a teaching method.

The remainder of this paper consists of a brief description of traditional GMB; a review of an evolving approach to teach SD as part of master courses; a description of a GMB approach as basis for student SD modeling projects; a justification of this GMB approach for student SD modeling projects; evaluation of experiences; and a concluding discussion with issues that need more investigation.

2. Traditional Group Model Building
Traditional GMB is a process designed to develop consensus and support for organizational interventions. The GMB workshops are facilitated by a team, consisting of facilitator, modeler, process coach, reflector, recorder and gatekeeper [3]. The modeling team employs knowledge of personal and interpersonal psychology to elicit information and construct a shared perception of complex problems from which conceptual model structures are developed in joint participation of modeling team and domain experts (client / problem owner).

During GMB workshops the modeling team employs different tools and techniques (stakeholder analysis, behavior-over-time graphs, dynamic stories, model structure diagrams among others) to elicit the
client’s knowledge on the analyzed problem. For example, behavior-over-time graphs are used to represent the evolution of key problem variables within different scenarios. Client representatives (domain experts) work in small groups, and present their findings in plenary sessions afterward. Consensus building discussions, sometimes shortened through voting exercises, consolidate the findings. These findings are used for sharing perspectives over the problem among the domain experts, to sketch the structure of the simulation model, and to validate and test the model. Finally, this model is used to derive policy recommendations for organizational intervention. For an extensive exposition of GMB see ref [8].

3. Teaching system dynamics in project-oriented master courses

The System Dynamics Society’s homepage (http://systemdynamics.org) defines system dynamics as “…a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems – literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality.” (The quote is originally from ref. [14].) It is no secret that many system dynamicists are puzzled as to the relatively low adoption of SD, the perhaps most disturbing aspect being the stagnation in membership numbers since 2005 (Table 1). Taking the total number of members in the System Dynamics Society as proxy for SD expertise around the world, one may conclude that despite its notable successes SD still is not as widely in use as one would expect. Indeed, since SD’s inception in the 1950’s studies using SD have delivered key insights for better organizational performance in areas as important as quality improvement [15] and project management [16]. More examples are found in recent excellent expositions of SD [17-21]. One is tempted to ask if the lower than desired adoption of SD might, at least in past, be due to how the discipline is taught in university courses.

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Master studies dedicated to system dynamics are rare. SD is mostly learned in courses belonging to master studies in management, organizational science, environmental science, etc. (For an overview of such courses and studies, see “Courses in SD”, in the “Resources” section of the System Dynamics Society’s homepage).

The author of this paper teaches system dynamics as part of master courses in security and in industrial and information management at the University of Agder, Norway. Until 2009 the courses had a size of 10 ECTS (European Credit Transfer System), corresponding to 1/3 of a semester workload. Since 2010 each course has been split in two 5 ECTS courses that are delivered in different semesters. A study year consists of two semesters.

The 10 ECTS courses consist of lectures, non-obligatory exercises and five obligatory modeling projects. They comprise an introduction to the basics of system dynamics followed by a final part (approximately 30% of the course) dedicated to applications of SD to information security and applications to supply chains, for respectively Information & Communication Technology and Industrial & Information Management students. Since 2004 the courses have been taught in English, reflecting the significant proportion of students from outside Norway (most of them coming from China).

After splitting the 10 ECTS courses in two 5 ECTS courses the number of obligatory modeling projects has been set to two such projects per course. Projects require modeling a case and writing a report of ca. 12 pages. Students have one week to model the problem and write the project report. They are required to pass the project assignments in order to be allowed to take the final examination. The projects during the course are graded by one person (that is, the author of this paper) and they each count 5% to the final grade. The final examination is also project-based and, again, it takes one week’s work. The final examination project counts 75% to the final course grade. The final examination project is graded by two persons: an external examiner and the author of this paper. This involves separate initial grading and a meeting to resolve possible differences in grading.

Immediately after project delivery, students have to take a multi-choice examination that centers on project relevant issues. The examination checks if the students have a theoretical understanding that matches the quality of the project report. Another check is done by using Ephorus (https://www.ephorus.com) to detect
possible plagiarism. Students are aware of this, and as a general rule the multi-choice exams and the check for plagiarism deter attempts to cheat. This said, students are free – and even encouraged – to discuss problems with peers during project execution, provided that the project reports are written individually. There is evidence for project collaboration from the students’ course evaluation. All in all, the variation in quality, as expressed by student performance marks, seems to indicate that such ad-hoc collaboration is compatible with a satisfactory degree of characteristics allowing the assessment of individual learning.

Project-based assignments requiring active application of the new knowledge are common in academic courses. (See e.g. SD courses at the University of Bergen, the MIT SD courses and the new European Master Study in System Dynamics – all accessible via the System Dynamics Society’s homepage.) Also, most of the student ‘challenges’ in Sterman’s SD textbook [17] have the form of an academic assignment.) Such challenges can be considered “case studies”.

The author’s long teaching experience (nearly 40 years) has formed the following impression:

• As evidenced by the submitted reports and papers, most students are not careful readers of assignments and examination papers – important points are often overlooked or misunderstood.

With regard to projects consisting of modeling a case, such reading deficiency is a strong impediment for correct problem identification and conceptualization. Thus, how to improve the students’ reading ability is a central issue (with transfer value to other subject matters and tasks depending on challenging written information).

• Many students are uncritical, and they seem not able to assess the quality of the model or the report that they produce.

Lacking quality control, long-term knowledge (knowledge structures about task work) does not accrete satisfactorily. Thus, teaching students to develop and use quality criteria must have high priority. This implies that students should be required to perform a self-assessment based on quality criteria, and that such self-assessment should be part of the students’ project report.

• Pure grading – i.e. just giving the student a mark such as A, B, C … (even if it is finer graded, such as A+, A-, B+, B-, …) – is not very helpful. (Students do not improve much from such “feedback”.)

‘Feedback’, in the sense of the teacher’s evaluation of the students’ performance, should be explicit, it should use quality criteria, and it should deliver a clear assessment of the model developed, the report and even of the quality of the students’ self-assessment.

The implementation of these requirements in the author’s courses has evolved over the years, with changes and improvements based on insights from previous courses. The consolidated approach as to 2009 – still not using GMB as teaching method – satisfied the following requirements:

1. Students must identify project tasks and depict them in a Gantt diagram, which must be part of the project report. The quality of the Gantt diagram is a proxy for the quality of reading of the assignment.
2. Students must develop measurable and verifiable criteria to assess the project tasks, again to be included in the project report.
3. Students must use the Gantt diagram actively during project execution and to perform regular assessments of task execution using the quality criteria.
4. Students must perform, and include in the project report, a final self-assessment with proposed grading for the tasks – including quality of Gantt diagram, use of performance criteria, quality of report writing and reflection on the self-assessment.

All in all, the approach targets metacognition by instigating students’ reflection on performance. Each student gets an individual project evaluation report. The report comments favorably on achievements, identifies shortcomings, misperceptions and errors, with suggestions for improvement, and it provides grading for each task – both those identified by the students and tasks missing. In addition to the individual reports, a generic report is shared with all students. The generic report can be considered a report on lessons learned. It summarizes findings, identifies commonalities and exceptions, and it provides guidelines for improved performance.

The experiences with the teaching approach can be summarized as follows:

1. Students reading abilities improve during the courses, slowly first and with a marked improvement toward the end of the courses. Still, the quality of task identification serving as proxy for reading abilities serving significant room for improvement.
2. Developing appropriate assessment criteria does improve during the courses, but far from enough. Students struggle with this aspect.
3. Even with imperfect criteria, students learn from self-assessments and exhibit better project performance, with an upward trend during the course. Performance decline is very rare and then mostly sporadic, without a noticeable trend.
4. Self-assessment, to start with quite poor in the average, improves notably and steadily during the courses.

An external examiner, who is a member of the department of system dynamics at the University of Bergen, commented favorably and repeatedly on the student performances. The role of the external examiner is to check that the grading of the student performance is as objective as possible.

The students are required to assess the courses by providing a collective written course evaluation report. The message from the students has consistently been that the learning experience is better than with traditional teaching methods, but the workload is also higher. Some students even complain that the workload is excessive. In depth interviews and discussions with the students reveal that the requirement to develop a project plan and a self-assessment based on measurable criteria make students conscious of aspects that otherwise would be overlooked, thus increasing the workload beyond the students’ expectations. When confronted with seemingly larger demands most students tend to work harder. The desired transition to working smarter requires a change in learning habits, with metacognition [22, 23] as driving force. Metacognition is cognition about cognition, and it requires introspection so as to observe and experience, regulation of activities to control learning and awareness (knowledge about oneself and others as cognitive processors). Our approach instigates metacognitive processes but developing new learning habits take typically longer time than a one semester course.

4. Description of Group Model Building as teaching method in system dynamics courses

A starting point for collaborative modeling is the observation that even modest improvements in task identification, quality criteria and self-assessment seemed to trigger a significant improvement in modeling and in report quality.

To capitalize on this observation that there seems to be leverage in improving identification of tasks and assessment criteria, we introduced in 2010 a GMB approach targeting these aspects.

The case to be modeled in a student project is made available at 8 am using the open learning platform Fronter (see http://com.fronter.info/). Students are required to read the case description in advance of the GMB session, which occurs during the afternoon of the same day. The GMB session uses a facilitator (the teacher of the course, that is, the author of this paper). During the GMB session the students act as “client team” who are interested in achieving a complete SD model of the case building on the outcome of the GMB session. A “complete SD model” means a model that addresses the problem case, that can be simulated, that is validated and tested, and that it is documented in the reports produced by each student in a basically individual effort after the GMB session. (A note as to validation: the case description provides requirements for the expected validation, with demands adapted on course progression.)

During the GMB session the students perform as domain experts in the sense that they contribute with their understanding of the case in a collaborative effort to a) identify the project’s tasks as basis for a Gantt diagram; b) define measurable quality criteria for project tasks; c) identify key problem variables and their reference behavior modes. Each of a), b) and c) involve working in groups; labeling / drawing on A4-size sheets; and presenting the group results in a plenary session. The group size can be adjusted so as to have a maximum of four groups. The class size varies from about 8 to 25 students, depending on whether the course is optional or obligatory.

The role of the facilitator is to keep the process running smoothly. If problems arise, the facilitator acts as coach by asking questions that help the students to navigate safely.

The materials are fixed to the wall with stickers (after clustering as required, to aggregate in categories).

After the GMB session, and for the remaining 6 ½ days (4 ½ working days if the weekend is discounted) the students act as recorders and modelers of a traditional GMB modeling team would do. Students are advised to consider the product of the collaborative session as raw materials for the individual modeling process, which can include some cleaning up and refinement of the GMB products. As in traditional GMB processes the (student) modelers develop a complete SD model and write a documentation (which in this case is part of the project report).

5. Justification of Group Model Building as teaching method

A justification of the approach is needed. Two issues must be addressed:
1. Is a GMB approach compatible with the requirement that the students’ performance should be assessed individually?
2. Are the conditions for a GMB approach in place for a “team” of students following a SD course?
Issue #1: Owing to collaborative modeling the GMB approach does produce collaborative outcomes that in principle can benefit all individual performances. However, the benefit derived from collaborative modeling is restricted to a) Gantt diagram; b) quality criteria; and c) key problem variables – as described in the previous section.

After the GMB session, which takes one afternoon, the students still have 4 ½ working days left for individual work until the project delivery deadline. Notwithstanding the possibility of ad-hoc collaborative work among the students after the organized collaborative modeling in the GMB session, the strict controls described above seem to ensure sufficient characteristics for individual grading.

Issue #2 requires clarification of whether the students satisfy the condition of being a “team” as well as to which are the role of the students in the GMB session.

During the GMB session the student class can be described as a team in the sense proposed by Salas, Dickinson, Converse and Tannenbaum [24]: “a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life span of membership”.

As to the role, as described in the previous section during the GMB exercise the students act as client or problem owner. By having read the case in advance, students carry with them an understanding of the problem. As with traditional GMB workshops, the knowledge about the problem in case is fragmented. It is assumed that although no participant has complete knowledge, the team knowledge is complete, but tacit.

6. Reflecting on the approach and looking forward

The collaborative modeling approach described above has been used in two courses so far. Thus, even if the GMB experience seems to improve a teaching approach that has been evolving during a ten year period, there is no sufficient basis yet to draw robust conclusions. Nevertheless, it seems convenient to communicate the essentials of the approach to colleagues who share an interest in collaborative modeling and looking for new ways of teaching. The collaborative learning approach could be tested in other courses which employ case studies. The fact that most students suffer from two basic deficiencies, 1) problems to read cases challenges accurately, and 2) failing to perform quality control owing to lack of criteria and thus (see p. 3), have generic implications.

The rationale for collaborative modeling of case studies might be more fundamental than just addressing two such basic deficiencies. Recent work on team evolution, maturation and adaptation point to the memetics of problem solving as a promising road for insights in collaborative learning and modeling [25, 26].

Memetics – the theory of memes – is still a young discipline. It started with Dawkins’ famous book “The Selfish Gene” in 1976 [27]. The conditions for the occurrence of genetic evolution can be summarized as inheritance of traits in the descendants, the occurrence of variations / mutations of inherited traits, and differences in fitness to adapt to selection pressure [28]. These conditions are satisfied in the gene as the unit of replication in living systems [29].

Dawkins posed the question if other replicators than genes existed, that is, entities that would be inherited with variations that are subject to selection pressure. In “The Selfish Gene” [27] Dawkins argued that the meme, defined as “a unit of cultural transmission”, did satisfy such criteria. Memes are replicated by transmission from person to person (imitation). Such “replication” is not perfect, resulting in variations in transmission and adoption probability. As a consequence cultural evolution occurs. Much discussion has ensued as to how memes should be defined, and there is an extensive literature (and much controversy) on memetics. Increasingly, memetics has been applied to cognition and learning (such as mathematical cognition [30]) and team problem solving [26].

Rosen, Fiore and Salas [26] explore socio-cognitive processes that operate in the transmission and mutation of problem solving memes in teams, in particular in the problem identification and conceptualization phase. Rosen et al. argue that problem identification and conceptualization in teams are driven by shared knowledge structures and shared cognition. Shared mental models about roles and skills of team members and of the problem space are basic requisites for effective team problem solving. Other important aspects are Team Situational Awareness (TSA), the dynamic knowledge structure representing the team current understanding of the problem space, and the Team Problem Model (TPM), a shared understanding of the nature and cause of the problem, the meaning of available cues, the dynamics of the problem under different circumstances (in SD parlance: the behavior reference modes), the desired outcome and a shared understanding of the solution strategy. The last should include the dynamic hypothesis if the problem concerns SD modeling.
According to Rosen et al. [26] inheritance in team problem solving occurs through the socio-cognitive mechanisms that transform individual level knowledge in the team (share mental models) into team level dynamic representations (TSA and TPM). Memetic mutation in team problem solving originates by interacting within the team. Finally, TSA contains information that will determine to which degree memes of problem solving are effective and, thus, determine if there are successful, in the sense of increasing their adoption. TSA also contains goals that influence purpose-driven mutation of memes.

Arguably the cognitive literature of GMB has concentrated on the personal and interpersonal psychology of group processes so as to improve the methodology of collaborative modeling.

It would seem that there is an exciting landscape of collaborative team learning and team problem solving that asks for more research, both in terms of pedagogical aspects of problem solving disciplines (including SD) and in organizational learning of problem solving (even when the team in question are client representatives playing the role of domain experts).

In particular, research efforts to identify the memes involved in SD modeling, the socio-cognitive mechanisms that replicate / transmit such memes and select memes in collaborative SD modeling might prove an effective way to enhance learning and applying SD. If this succeeds, more collaborative modeling might be instrumental to establish SD as a mainstream modeling method.

8. References

1. Roberts, E., Strategies for effective implementation of complex corporate models, in Managerial Applications of System Dynamics, E. Roberts, Editor. 1978, Productivity Press Cambridge, MA, USA.


