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The "Ticket to Ride" Formative Assessment Ritual: Collaboration and Festivity in High School Chemistry

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ABSTRACT: Chemistry taught in high schools typically has group interaction components designed to provide opportunities for groups of two or more students to collaborate. Such opportunities, however, can lead to diminished learning among some students, as domination, group dissonance, and/or non-participation among group members can derail the collaborative effort. Can the strategic formulation of groups enhance performance on traditional collaborative chemistry activities conducted within these groups, and can the establishment of a festive formative unit assessment strategy contribute to improved individual and aggregate achievement while improving group coherence? This paper describes a decade-long effort to ameliorate pitfalls common to group learning in two small, rural high schools in Wisconsin. This effort combines a suite of approaches, including: meta-cognitive strategies for establishing long term, heterogeneous groups; fostering group adhesion through development of common achievement incentives; development of collaborative assessment strategies; and creating a festive and ritualistic classroom environment.

KEYWORDS: *General Public, High School/Introductory Chemistry, Curriculum, Collaborative/Cooperative Learning, Testing/Assessment, Topic: Learning Theories*

■ ORGANIZATION OF THE CLASSROOM: SETTING THE STAGE

With a Little Help from my Friends

Louis Schmier, professor of history at Valdosta State University, has employed the establishment of "triads" in his courses for many years. Triads are groups of three students that work together for an entire semester; in Schmier's course, these groups are encouraged to collaborate in discussions and assignments during class and to organize and participate in study groups outside of class. He asserts that three is the magic number; groups of two often do not have adequate breadth of input while four in a group can result in "free-loading".[1] Recognizing the historical importance of laboratory activities and experiments in traditional high school chemistry courses, an experimental design was created (and carried out for a decade) in which students enrolled in introductory chemistry classes were organized into heterogeneous triads that would remain together for an academic semester. Accompanying this grouping arrangement was the development of a formative assessment strategy that allowed the students to assess their own readiness for unit exams while allowing the teacher to assess targets of learning as the unit exam approached.

This organizational strategy began on the first day of the course in 1998, initiated by the administration of the True Colors leadership inventory[2] and the Myers-Briggs Type Indicator.[3] Aggregate classroom data (without student names) from these two inventories was collated by the teacher at the end of the day and distributed on the second day of class. Students searched for patterns within and across the two data sets in an attempt to find definitions of the terms "correlation" and "heterogeneous." They were also encouraged to quantify their correlations; e.g., "75% of the greens were introverts." Heterogeneous triads were established by the teacher (aided by the conclusions generated by the students' metacognitive effort) by the end of the second day; students grouped in their triads on the third day. Because of section shuffling at the beginning of the second semester, new triads are similarly formed at that time.

Because this was a chemistry course, the triads were called *families*. In recognition of Johann Wolfgang Dobereiner's 1821 arrangements of certain chemical elements in chemical *triads*,[4] each group of three students was assigned a family name from the periodic table and each member of the group selected a representative family element as his or her *nom de chem*. The abstract photo shows the 2006 Chalcogens; the members adopted S, Se, and Te.

Such element-adoptions were useful throughout the year, allowing human modeling of important chemical concepts such as bonding, electronegativity, ionization energy, and chemical and physical properties. Figure 1 shows one possible classroom organization scheme for a class of 18 students; from the students' perspective (facing the teacher), group number increases from front to back, metals are on the left, nonmetals are on the right. For larger class sizes, more families may be added (e.g., Tetrels, Pnictogens, Noble Metals, Rare Earth Metals, Coinage Metals). Even the instructor gets to portray an

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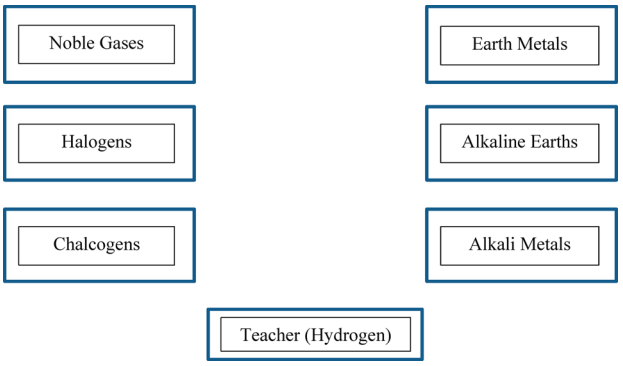

Figure 1. Example classroom arrangement for 18 students (3 students per station).

element; hydrogen is an important player in human modeling, but it defies classification as a member of one particular group.

SOCIOLOGIC IMPLICATIONS OF TRIAD GROUPINGS

All Together Now

The functionality of placing students in triadic chemical families can be tied to the field of developmental sociology. Sociologist Christian von Sheve asserts that individuals grouped together over time and focused on a common purpose can experience cognitive reinforcement and gain through the socio-cognitive display of "collective effervescence and emotions in rituals."[5] As these groups coalesce over time, von Scheve asserts that groups with well-established unity of focus and cohesion benefit *even more* from the "emotional contagion" inspired by the presence of ritual and common purpose in the learning enterprise. Robust, thought-provoking assessment items are well-suited to this environment.[6]

Cooperative learning is a popular classroom approach that enjoyed a surge in popularity during the mid-1970s through the mid-1980s.[7] In this paper, the term "cooperative learning" will include the related strategies *collaborative learning*[8] and *reciprocal peer learning*.[9] Research findings on the effectiveness of cooperative learning reveal both tenets and traps. *Group responsibility, group rewards,* and *individual accountability* are mantras that have saturated the cooperative learning lexicon.[10,11] Opportunities for students working in groups to self-assess and for them to be active participants in the assessment strategies are critical.[12]

However, chief among the pitfalls that must be confronted in assessing products of cooperative learning are issues of learning ownership, negative impacts of personality dissonance, and the inevitability of overinflation by group members of their own level of cooperation. Despite these pitfalls, classroom adoption of metacognitive strategies for engaging students in cooperative learning has been deemed successful in enhancing student learning.[13,14]

RITUALISTIC, FESTIVE, FORMATIVE ASSESSMENT

Ticket to Ride

Coupled with this grouping strategy, can assessments be designed to improve group cohesiveness and individual performance during classroom activities? It is from the backdrop of this triadic-family, reciprocal-peer-learning, heterogeneously grouped cooperative classroom environment that the "Ticket to Ride" (TTR) emerged.

The TTR is a formative assessment strategy. With recent emphasis in the U.S. on standardized testing, and the concomitant consternation among students, teachers, parents, administrators, and policy makers regarding assessment, the definition of "formative assessment" has been refined and formalized.[14] Formative assessment can perhaps be most effectively defined as what it is *not*; it is *not* standardized or high-stakes testing administered to determine a cumulative effect of a student's, school's, or state's gain, it is *not* a diagnostic instrument administered to determine placement in special programs, and it is *not* a method of acquiring data to be used as an accountability measure assessing teacher accountability. Formative assessment *is* an important pedagogical tool that, if used effectively and frequently, can provide data that teachers can use to inform selection and modification of instructional methods and that students can use to inform learning strategies. Though formative assessments can generally take on many forms, the TTR (specifically) is always brief, formal, planned, written, and unscored.

A TTR is a unit exam "forgiveness voucher" awarded to all members in a triad which has achieved group perfection on a formative assessment instrument administered on the day prior to a unit exam. This instrument adheres to several fixed constructs; it is always administered on the day *after* the unit review and *before* the unit exam; it is *always* comprehensive over the unit material; it is *always* confined to one side of standard paper with 12-point font and 1-in. margins; it is *always* completed individually and submitted *anonymously* in a triad-identified envelope; and it is *always* designed to take no more than 20 min to complete. To ensure security within the triads, three different (yet similar) versions are prepared and distributed to members of the triads. Possibly *because* these formative assessment instruments are nongraded and non-punitive, their enactment evolves into a motivational, ritualistic, and festive event over time. Incentive for all students to participate *daily* in classroom activities (including laboratory exercises) and to actively support each other leading up to the TTR is implicit in the challenge: In order for the triad to achieve success, each member's submission must be *perfect*. Individual success is thereby linked to group success; however, students know that they are not being graded on other students' work. The TTR is an opportunity, not a judgment.

The last day of the unit, traditionally *review day* for the unit test, becomes instead a rehearsal for the next day's TTR event. The final few minutes of the class are provided for groups to organize and to self-assess their readiness and to ask clarifying questions of the teacher.

THE CLASSROOM SETTING

Imagine...

You are the instructor. It is the day after the unit review in your high school chemistry class. You have been teaching the topic of chemical bonding, or thermodynamics, or stoichiometry. The stage was set yesterday during a formal review of the unit's material, the traditional "give-and-take" dirge to which countless students (and their teachers) have shuffled on the road to "Judgment Day." Yet...today is different; students arrive early, hurriedly assembling in their triadic families to spontaneously engage in purposeful peer learning strategies, including organizing for learning,[15] probing for knowledge,[16,17] peer coaching, and focusing on task preparedness. Some groups have already met the previous evening and/or early this

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morning. Classroom observers might describe the setting as energetic, or chaotic, or perhaps even *festive*. The Beatles' tune, "Ticket to Ride,"[18] is looping quietly in the background. In facilitator mode, you move among the groups, reminding the more assertive "leaders" to be attentive to all members of the "triad" while gently encouraging visibly timid students to become more actively engaged. You praise each question and ensure the students that a full-class discussion is warranted. After 10 or 15 min of intense intragroup rehearsal, the class reconvenes as a large group; the Beatles continue to quietly serenade the students as they bring remaining great questions to the floor. This is an opportunity for triads to seek clarification while allowing the instructor to probe for incomplete understanding and misconceptions. When all are satisfied, distribution of the formative assessments commences, and a tense quiet almost fills the space.

Things We Said Today

Upon completion of the one-page assessment, each triad member folds and places his or her work into a business envelope to which a chemical group name is affixed; student names on the individual instruments are unnecessary. At stake is the coveted "Ticket to Ride". These are free passes for each member of the triad, to be distributed to members of successful triads tomorrow, worth an automatic 100% on the next day's exam. These "TTRs" are, however, very difficult to obtain. The price tag is perfection; not merely perfection by one member of the triad, but complete perfection by each member of the group.

After all envelopes have been collected, you encourage the students to debrief within their triads. Eagerly, the students probe one another to find out what was on the other forms, how they think they did, how they arrived at the answer. Because each student's success is linked to the success of the group, they are very attentive to each other's stories. Some triads begin preparing in earnest for tomorrow's exam. A review sheet (Figure 2) including all three forms of the assessment instrument along with solutions to one of the instruments, is prepared and is available to all students by the end of the day.

Do You Want To Know a Secret?

At the end of a festive day, you open the envelopes and scrutinize the students' work. Triad perfection is the only qualifier, so your marking pen lies dormant. Your attention is laser-focused, identifying student misconceptions, common errors, and particularly troublesome problems and concepts. You may find yourself quietly rooting for perfection; each successful triad reduces (by three) the number of exams you will have to grade. You are done in less than 30 min.

You will use the data to synthesize last-minute intervention strategies to share with the students in the minutes preceding the administration of tomorrow's exam (if the assessments reveal severe and/or widespread student deficiencies, and if your syllabus allows for it, you may decide to delay the exam and spend the next day in a reteaching mode). Triads achieving perfection will be asked tomorrow to sign their "masterpieces", later displaying them prominently on a classroom wall, thus creating a comprehensive review instrument for semester or final examinations.

Yesterday

You will probably observe students entering your classroom on exam day displaying a noticeably different attitude than exam-bound students displayed in the years prior to the TTR implementation. Students entering your classroom realize that two tasks remain: (1) a brief review of yesterday's TTR (no more than 10 or 15 min for a 52 min class period); and (2) the unit exam (or receipt of a "ticket"). As you begin with a discussion of your findings from your analysis of yesterday's assessment, you can sense the crescendo of anticipation building through this final pep talk. As you begin the distribution of exams, students are staring at the small stack of "tickets" held in your hand. You ceremoniously distribute these to members of successful triads, and these rewarded students can be released to the library, computer lab, or remain in the classroom. Sometimes these students choose to work quietly with classmates who have been absent. Students taking the exam notice that the format, sequence, and cognitive level of the questions are the same as what they had already experienced the day before. Though the unit exam is similar to yesterday's TTR, it is not identical. Alternate and more thorough representation of question and problem types are apparent, as there is no longer a one-page limit.

TTR Form 1	TTR Form 2
TTR Form 3	Solution (Choose 1 to complete as an answer guide)

Figure 2. Copier arrangement (4:1) for creating single-sided, 1-page study handouts.

REFLECTIONS

Don't Let Me Down

Through the 10 years of deployment of the TTR strategy in two different high schools, a few common questions and statements have arisen, and these (along with appropriate answers and explanations in parentheses) are revealed below:

"Who messed up?" (I will not reveal that information; however, you should focus on teamwork and on solidifying your preparation before the next opportunity.)

"How do I know if I messed up if you don't return the TTR to me?" (It is important that individuals in the group are not singled out for making errors. The review sheet is available at the end of the day. It shows all three versions of the TTR along with the correct responses for one of the three. Work through the examples and confer with other members of your triad.)

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"We have a member who doesn't care/do enough or is absent too often." (What have you done to encourage this member of your group? How can I help?)

"Are we allowed to "make up" a TTR?" (No, if you miss the TTR day, you will have to take the exam.)

"The same groups always get it!" (Good for them! Your group should find out what they do to prepare.)

[Parent]: *"I've never liked group work because my child is being graded based upon the work of others."* (Actually, in a traditional setting, students would typically take an exam at the end of the unit. Your child's performance on the TTR qualifying assessment is neither individually recorded nor aggregated to arrive at a group score. It is merely an opportunity for students, working in consort, to be rewarded for collaborating in an effort to demonstrate individual and group perfection.)

Through time, most of these "FAQs" were anticipated and addressed preemptively, but in the beginning, these contentious issues were a source of student and parent anxiety:

Eight Days a Week

As other teachers have considered employing the TTR strategy in their own classrooms, good questions have emerged. Chief among these is the "Eight Days a Week" dilemma, summarized by the argument that the strategy adds an extra day to each unit, thus reducing the quantity of content "covered" in the course. Quite possibly the addition of this "extra day" may not be a dilemma at all, as dismal failures on unit exams are nearly eliminated.

The triad group structure may also dissuade teachers from adopting the strategy, as science teachers typically have classrooms and/or labs that are arranged to accommodate groups of four or two. Curriculum products may also focus on group sizes other than three, such as SEPUP's "4-2-1" approach to cooperative learning; equipment and materials are available for lab groups of four, activities are completed by pairs of students, and each student is responsible for analyzing the data and summarizing the results, assuring individual accountability.[19] Though triads are preferred, other group sizes or arrangements may be attempted.

As section enrollments in high school chemistry courses trend higher and instructor time gets thinned, the importance of fostering meaningful group activities and dynamic interactions among students becomes even more critical. In large undergraduate collegiate chemistry sections, the TTR strategy can be employed in consort with such innovations as classroom space optimization[20] and technology-enhanced delivery modes.[21]

Magical Mystery Tour

The TTR strategy was employed in an introductory chemistry course for six academic years (1998−2004) in a rural, northern Wisconsin high school with average enrollments of about 350. Beginning in 1987, all introductory chemistry students were administered Part I (40 prompts) of the 1985/1985S ACS High School Chemistry Examination at the end of the school year. Beginning in 1995, data showing yearly high school and chemistry enrollments and mean scores were recorded. The TTR strategy was deployed in 1998. It is important to note that completion of introductory chemistry was not required; two credits of science satisfied the graduation requirement. Due to numerous confounding variables, these results cannot reliably be attributed solely to the TTR strategy. However, pre- and postimplementation trends in these two areas can be observed in the percentage of students enrolled in introductory chemistry and in the yearly aggregate mean score of students taking Part I of the 1985 ACS High School Chemistry Exam (Table 1).

Table 1. Enrollments and ACS High School Chemistry Exam Raw Data (1995-2004)

Academic Year	High School Enrollment	Intro. Chem. Enrollment	% of HS Students in Intro. Chem.	Mean Raw Score
1995−96	421	42	10.0	20.8
1996−97	433	39	9.0	21.1
1997−98	413	40	9.7	20.2
1998−99[a]	410	42	10.2	21.8
1999−2000	399	46	11.5	22.2
2000−01	391	54	13.8	21.9
2001−02	383	47	12.3	23.0
2002−03	339	38	11.2	22.1
2003−04	323	35	10.8	23.4

[a]TTR strategy first adopted at the beginning of the 1998−99 academic year.

A similar strategy was employed in another rural Wisconsin high school from 2005 to 2009, and although the ACS exam was not administered, enrollment in Introductory Chemistry more than doubled over that time span. Popularity of the course led to the addition of a section of "Advanced Chemistry" in 2007−08; two sections were needed in 2008−09.

Come Together

An essential component of the TTR strategy is an emphasis on perfection, ritual and festivity. Familiarity engenders success, as each unit progresses in exactly the same way. Multiple attempts are made throughout the unit to ensure student understanding. The teacher is able to recognize and address student misconceptions, naïve conceptions, and concepts in need of further clarification "just in time." Working in triads, students can engage in a meaningful and memorable collaborative effort, with clear and attainable rewards for good work. Clarity of purpose permeates the ritual (for the teacher and for the students), and though *excellence* is certainly achievable by all students, *perfection*, individually, within the triad, and across the entire class is the principal target.

A member of the first chemistry class to have experienced the Ticket to Ride expressed her recollections of the strategy:

> *I took Introduction to Chemistry during the inaugural year of Ticket to Ride. The day of the Ticket to Ride exam was an unusual mix of excitement and anxiety unlike any other high school assessment, as if Homecoming was happening on the same day as the ACT, all backed by a Beatles soundtrack on loop. While I initially chafed at the idea that my success on the Ticket to Ride was contingent on the success of the other members of my chemical family, I found myself retaining the information better because I couldn't just drill; I had to know the information well enough to teach it to my classmates. It wasn't until years later, when I learned about Bloom's Taxonomy, that I realized how much more effective this kind of learning was.*

Recently, a typical Facebook "nova" of 18 additional testimonials appeared in one 24-h blast. These are written by former students who are half-a-lifetime removed from high school chemistry. Among these ("in the raw"):

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...Thank you for being such an awesome chemistry and advanced chemistry teacher to me in high school! Its because of you I got such great grades and get to skip college level Chemistry!

...I might not have been allowed to skip the college chem course I needed, but I sure as hell never had to open my textbook to get an A.

...By far best teacher hands down! I have never been so proud of myself as I was in your class when I FINALLY got a ticket to ride! Lol

...To this day I still love everything about chemistry and my son is already into it he plays a game called toca lab!

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Notes

The authors declare no competing financial interest.

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