# Advancing a New Perspective on Decision-Making about Socio-Scientific Issues: The Study of Memes and Memetic Processes

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**Abstract**: The study seeks to advance the socio-scientific issues knowledge base by addressing the complexity of these issues using methodological and analytical tools that reveal information about individual, collaborative and situational outcomes. In this case study of a grade 7 classroom investigating the topic of genetic engineering, a memes analysis indicated that several memetic mechanisms potentially affected how and why ideas were taken up in the learning system. Mechanisms included processes such as 'do as the smart students do', friendship selection, and meme-coupling influences. Implications for education in terms of student decision-making about socio-scientific issues are discussed.

## Argumentation, Socio-Scientific Issues and Complexity

As a challenge to traditional practices of school science, a substantial body of research has advocated for educational experiences to simulate the discursive practices of the scientific community that are predicated on language, communication, and argumentation (Driver et al., 2000; Newton et al., 1999; Osborne et al., 2004). Argumentation enables the critical evaluation of scientific and technological claims (Driver et al., 2000), develops logical reasoning skills (Osborne et al., 2004), encourages the use of evidence to challenge and support theories (Sandoval & Millwood, 2005), creates classroom environments that promote multiple perspective taking (Driver et al., 1994), requires active participation and co-construction of knowledge (Newton et al., 1999), and engages students in decision-making about scientific and technological issues (Jimenez-Aleixandre & Pereiro-Munoz, 2002). Researchers have sought to document student attitudes and beliefs about socio-scientific issues and have also investigated the efficacy of curricular interventions on student learning that incorporates many of the necessary reasoning, argumentation, and decision-making skills listed above. Results have shown that students hold a wide range of beliefs about what is acceptable use of certain socio-scientific research (Dawson & Schibeci, 2003). They also lack an understanding of essential processes and often display widespread uncertainty about socio-scientific knowledge (Lewis & Wood-Robinson, 2000). Moreover, despite extensive curricular interventions, some studies have found that student attitudes largely remain unchanged (Dawson & Schibeci, 2003; Olsher & Dreyfus, 1999).

Sadler (2004) presents detailed and plausible recommendations for researchers to pursue in order improve student attitudes and beliefs however much of the literature reviewed focuses on interventions that involve students interacting with concepts and issues through teacher or researcher selected texts. The same article acknowledges that socio-scientific research often involves cutting edge or frontier forms of scientific activity, thus people need to rely on multiple sources when forming opinions about such research. This situation suggests that the manner in which students acquire and evaluate these information sources must be studied in addition to studying their reasoning abilities or understanding through text analyses. Several researchers have also stated that some of the difficulties in understanding socio-scientific concepts lie in the inherent complexities of these issues and provide insights into constructing programs that both encourage access to and evaluation of these multiple decision influencing sources, which include peers. For example, Kolstoe (2000) advocates for a process of consensus-building in projects premised on the presentation and defense of data with the expectation that ideas are debated, opposed and negotiated by fellow classmates (there are other robust and long-standing research programs, e.g., Bereiter, 2002 that do not focus exclusively on socio-scientific issues but nonetheless promote similar knowledge-building peer-to-peer activities. Hmelo-Silver and Azevedo (2006) suggest that learning how to design appropriate and effective curricular contexts when dealing with complex scientific phenomena, requires efforts by researchers to investigate the cognitive, metacognitive, and motivational skills and strategies that affect not only the individual, but also collaborative and situational outcomes. The study seeks to advance the socio-scientific issues knowledge base by addressing the complexity of socio-scientific issues using methodological and analytical tools that reveal information about individual, collaborative and situational outcomes. As part of a larger research program investigating the efficacy of a complex systems approach in science and technology education (Yoon, 2007) this smaller study investigates the subfield of memetics (e.g., the study of how information moves across cultural systems as well as individuals) that attempts to address the aforementioned problem of understanding how students acquire and evaluate information sources. The question under investigation is: What educational insights do the study of memes and memetic processes provide in terms of understanding what and how students learn about socio-scientific issues?

## Memes and Memetic Processes

Hogan and Maglienti (2001) found among other things that scientists and non-scientists (including middle school students) differed in their reasoning skills in that the former group drew on epistemological standards constructed by the scientific community such as the use of empirical evidence to make conclusions while the latter group used personal opinions to make judgments about knowledge claims. Kuhn et al. (1997) discuss the importance of dyadic interactions on improving a host of argumentation skills such as consideration of alternative perspectives and greater differentiation of justifications. Missing from the literature are studies that reveal why students have great difficulties reasoning in the first place. Studies in the social and psychological sciences on copying mechanisms suggests that there may be robust influences that stand in the way of effective reasoning skills. These copying mechanisms, also known as memetic processes, are thought to exert powerful control over decision making through informational units called memes that get passed on unintentionally from person to person through interactions. First introduced by Richard Dawkins (1976) in his book *The Selfish Gene*, over 25 years ago, the concept of the meme is generally understood to be a self-propagating unit of cultural transmission. Stanovich (2004) suggests that a meme "is a brain control (or informational) state that can potentially cause fundamentally new behaviors and/or thoughts when replicated in another brain" (p. 175). Dennett (1999) states that a meme "is an information-packet with attitude—with some phenotypic clothing that has differential effects in the world that thereby influence its chances of getting replicated". There is some contention in the literature about how to define a meme due to the lack of empirical studies in the field of memetics (Blackmore, 1999). However, a commonly cited characteristic of memes is that they are not always beneficial to the host and often act only in the service of their own ends. Thus, as Dennett (1999) states, they can be thought of as hitchhikers or symbionts that have more or less beneficial effects on the host. The mechanisms by which memes propagate—memetic processes—can therefore be explained in intentional vs. non-intentional terms or by reflective or non-reflective selection (Stanovich, 2004). Similar to the "virus" or "contagion" metaphor and popularized by recent books such as Gladwell's (2000) *The Tipping Point* and Godin's (2000) *Unleashing the Ideavirus*, non-reflective selection of memes are thought to be "caught" by the host irrespective of their utility or degree of benefit. Non-reflective selection may also be thought of as parallel to such concepts in memetic literature as non-content selection bias (Gil-White, 2004), socially based mechanisms of transmission (Castelfranchi, 2001) or unconscious selective forces (Dennett, 1999). Reflectively acquired memes conversely are ones that have been scrutinized against selection criteria, ultimately serve the ends of the host rather than the meme itself and are intentionally admitted to our corpus of understanding. They are equivalent to memetic selection through content selection bias (Gil-White, 2001), cognitively based transmission mechanisms (Castelfranchi, 2001) or methodical selection forces (Dennett, 1999). Most adherents of memetics would also agree that memes arise from social learning (Aunger, 2002), of which the principal medium of transmission is language (Dennett, 1995), creating the "infosphere" in which cultural development occurs (Dennett, 1995). From this description, there are obvious similarities to the argumentation literature in that language and communication are understood to be the primary sources through which arguments and decisions are made. This study presents an alternative but not mutually exclusive account of why understanding of complex socio-scientific issues might be difficult through revealing what memes and memetic processes exist in the science classroom.

# Methodology

## Participants

The research reported is a case study of one grade 7 classroom in which a complex systems intervention was employed. There were 18 student participants, ten males and eight females, with varying cognitive levels, social abilities and ethnic/cultural backgrounds from a junior high school in Toronto, Ontario. One-third of the students were, either formally or informally, identified as special education students and worked under modified individualized education programs while being fully integrated. Another four students were designated second language learners. The teacher participant, Ms. Saunders was an enthusiastic and energetic teacher who had a solid understanding of each student's social and cognitive history. She was involved in all planning phases and provided insight into the nature of group dynamics through observation notes, formal interviews, and informal discussions.

Although data was collected and analyzed from all participants, due to the complex nature of both individual level and group level patterns of interaction, and to highlight the notion that memetic processes exert influence both at the individual and group levels, a subgroup of six students in the class are profiled in the analysis. While population-based statistical analyses are normally used in cultural evolution and anthropological studies to demonstrate changes at the group level, an individual agent-embeddedness approach is used due to the belief that memetic processes can be most accurately understood at the individual level in educational settings. These six students detail cases of social and conceptual behaviors that best illustrate themes generated in the data and provide a rich context through which group level results are interpreted.

## Cognitive and Social Profile of Six Students in the Subgroup

The following information about students in the subgroup was gleaned from questionnaires, school records, teacher interviews and observations from researcher field notes. *Subgroup 1*: Ben and Natalie were highly respected members of the class in terms of their academic abilities. Both had a sophisticated understanding of current events and advanced verbal and written reasoning skills, relative to other students in the class. Each indicated on their preliminary questionnaires and in informal conversations with the researcher that they had heard of the term genetic engineering from media sources as well as their family members. Socially, both students appeared to have a good deal of influence on others. *Subgroup 2*: Thomas was one of six students in the class identified with a learning disability. Yasmin was an English language learner and frequently experienced difficulties comprehending written materials and verbal instruction. What set them apart from other similar students in the class was that they had developed fairly advanced coping strategies. For example, over the course of the study, they publicly asked questions for clarification and often took advantage of after-class review sessions. While maintaining a few close personal friendships in the class, they held low status amongst their peers. *Subgroup 3*: Greg was highly regarded academically. He received excellent grades, was an active participant in all school-related activities and was the most popular student in the class. Marshall was exceptionally bright and was not challenged by the standard curricula. He often appeared bored or distracted. Despite his enormous potential, he was an underachiever. Greg and Marshall were best friends with differing social status, i.e., Greg having hi status and Marshall having low.

## Context, Data Sources and Analyses

The study took place over 17 days and 24 hours of instructional time. Students explored a number of multimedia and print materials on the socio-scientific topic of genetic engineering including xenotransplantation, cloning techniques, ethical issues in the genetic engineering of animals and genetic engineering applications in crop farming. These materials were carefully chosen to represent a variety of critical arguments both for and against genetic engineering research. The pedagogical strategies used to promote the learning of concepts were designed to develop deep and complex understanding of the issue. These strategies included constructing risks/benefits charts examining tensions between environmental and societal goals; developing concept maps of relevant social, political, economic and environmental stakeholders; participating in several whole class *cocktail parties* (described below); and debating special interest group positions in a town hall meeting.

The majority of analyses were completed using data generated from three *Thinking Tags Cocktail Party* (1) activities. This was designed to simulate a discursive environment in which argumentation processes would spontaneously emerge. Students were required to rate the question, "Human use of the natural world for genetic engineering purposes is acceptable," on a number line ranging between –5 (unacceptable) to +5 (acceptable) and provide rationales for their rating. Students were then asked to share their ratings and rationales in paired discussions with every student in the class. Each student was required to wear a wearable computer called a Thinking Tag (Colella, 2000), which displayed how many people they talked to and the number of students who agreed with their statement. After each discussion, students were asked to register one of three votes on their partner's Thinking Tag: *Yes, I agree with the rationale*; *No, I do not agree with the rationale*; or *I am undecided*. Each Thinking Tag was programmed to keep a record of which students had met and at what time, each partner's respective ratings and what each student had voted after their paired discussions. This cocktail party activity was performed three times; at the beginning (Day 2, T1), in the middle (Day 10, T2) and at the end (Day 16, T3) of the study. A content analysis of 51 student rationales was completed in which 105 memes were identified (further description of the meme analyses follows in the section below). On Day 10 (T2) and Day 16 (T3), students were also asked to rank each student in the class from 1-18 in terms of the degree of like-mindedness. An in-degree score for each student was calculated from the average of students' like-mindedness rankings for each time sample (see Table 4). In social network analysis the in-degree score is a measure of the total number of connections that is directed toward an actor (Scott, 1991). In-degree scores can be used to represent an actor's prestige or status in a system (Wasserman & Faust, 1994). In the case of prestige or status, in-degree measures attempt to quantify the rank that an actor has within a given set of actors (Wasserman & Faust, 1994). In this study, the in-degree score was used to determine the status that either the students themselves or their ideas had within the larger learning system at different points of the study. Although the primary data sources were students' written rationales at each of the three time samples and the in-degree scores, some of the other data sources collected for the larger study were used for interpretation and triangulation. Chief among those were the sources generated from our teacher participant.

The selection of the units to be analyzed was based on ideas found in the rationales that could have a differential effect on how many students would agree with another student's rationale. Accordingly, *reasons or evidence used to justify a position or opinion* were deemed the unit of analysis. Meme clusters and meme types were superordinate constructs that emerged from the identification and labeling of the meme units. Meme clusters and types were first negotiated between the researcher and a graduate assistant. A categorization manual was constructed around 11 meme types within four meme clusters. Meme clusters emerged around: (a) ideas for or against genetic engineering research for anthropocentric purposes, i.e., the natural world exists only to serve human ends; and (b) ideas for or against genetic engineering research for biocentric purposes, i.e., the natural world has intrinsic value. A final category of meme type was added for ones that were not applicable or were unable to be coded due to ambiguity. Two raters with previous meme coding were trained. 92% inter-rater reliability was obtained on the entire data set of 105 memes. Codes for the eight memes in which discrepancies occurred were negotiated until a consensus was reached on the specific code to be assigned.

## Results and Discussion

Results from the meme analyses are organized into 3 tables for population or group and individual level perspectives on the data. Table 1 shows the 12 meme types that were combined and subsumed under the 4 superordinate meme cluster categories. Table 2 shows aggregate frequencies of meme types occurring in each category obtained from student rationales during each of the three cocktail party activities (T1-T3). Table 3 shows the frequency of meme types as they occurred in the individual student rationales in each of the cocktail party activities (T1-T3). Based on the memes analyses, data collected from the like-mindedness rankings and other data sources such as teacher participant observations, the following sections present memetic processes hypothesized to be operating in the classroom.

### Memetic Processes

In this section, three processes thought to be influenced by memetic mechanisms are described: i. 'Do as the Smart Students Do': The Influence of Status; ii. Identity Influences: and iii. Meme Coupling Influences.

#### i. 'Do as the Smart Students Do': The Influence of Status.

As previously described, social network in-degree scores were calculated from students' like-mindedness rankings. This data and analyses are presented in Table 4. A ranking of number 1 indicates that this student, Lisa for example on Day 10, held the highest status in terms of the aggregate student rankings on the like-mindedness criteria. By contrast, Mark on Day 10 occupied the lowest ranking. From Table 4, on the measure of like-mindedness, at T2, Natalie, Ben and Greg had the 2nd, 3rd and 4th highest in-degree scores. From all data accounts, the top four students in this category were considered the smartest students in the class. However, at T3, while Natalie occupied the top position, Ben's ranking moved to 11th, and Greg's to 18th. Thomas and Yasmin moved up in their positions from 8th and 11th to 2nd and 3rd respectively. What could account for such a seemingly unusual shift in ordinals? When these data were presented to Ms. Saunders, her response shed some interesting insight. She believed that the pattern was not unusual but rather exactly how the dynamics should have unfolded. Based on her professional experience, she felt that the topic of genetic engineering was cognitively advanced for a grade 7 integrated special education class albeit important to address given the potential for cultivating the curricular goal of complex relational understanding of scientific issues. In her classroom observations prior to T2, she felt strongly that the majority of the students didn't understand the concepts being addressed in the curriculum. This in addition to the method of instruction being so strikingly different from their normal classroom activities, for students who typically needed more time to settle into routines, it was likely that they chose a strategy of "do as the smart students do". In the face of learning challenges many of the students consciously or unconsciously identified themselves with the smartest students implying a selection force based on the social influence of status was operating at the group level.

There is some evidence to substantiate this claim. In the meme analysis data (Table 3), the rationales used to identify memes at all three time samples were constructed by students individually prior to any paired discussions occurring in the cocktail party activity. At T1, Ben's, Natalie's and Greg's rationales presented the most balanced and reasoned justifications to their ratings. For example, Ben wrote the following:

> I think this because sometimes we are helping the animals or we are hurting them. If we clone animals, those that fail will hurt the animal, bit if it does work we could help many people or things. Xenotransplantation is just hurting the animals because we have to kill them to complete the operation and we are not sure that it will always work, but if it does many problems would be solved for people who need organ donations.

This was Thomas's rationale for the same time sample:

> Why I think my answer [is] at 0 was because I think it's [w]rong to do that to animals and it's right because[there] will be more of them.

Comparing the two responses, we can see clearly that Ben presents two sides of the issue, uses terminology accurately and provides several pieces of evidence to justify his rating. Thomas however, does not provide substantive evidence. It is also not entirely clear what he means by the statement *it's right because [there] will be more of them*, suggesting that there is a lack of understanding.

The fact that Yasmin and Thomas moved into 2nd and 3rd position at T3 further substantiates the claim of "do as the smart students do" and suggests that a qualitatively different dynamic had emerged somewhere between T2 and T3. At T3, Thomas writes:

> I chose 0 because I think it's good and bad. I'll start off with good. Well, I think it's good because we are gaining more crops for use to survive. Now I think it's bad because when they do that process, we don't know if it is safe for us to eat because we don't know what is in it and we don't know what can happen…like if somebody gets ill or some one can die that's why I chose neutral.

A closer look at the curriculum concepts being addressed during that time sheds some light on the new dynamic. Just after the rationales were recorded at T2 the topic shifted from genetic engineering applications involving animals, to genetic engineering involving farming and crop manipulation. Thomas's response reflects the growing concern of uncertainty of future effects and safety issues surrounding genetically modified crops which was salient in the class's general conceptual system at T3. Table 2 shows the largest shift in meme frequencies in meme type 7 from T2 to T3. While Ben continued to provide reasoned arguments throughout the study, his rationale at T3 became entirely concerned with a 'cruelty to animals' idea, the meme type (9) that took the most substantial frequency drop from T2 to T3. It is suggested that students were no longer operating under the "do as the smart students do" mechanism but were now making decisions about like-mindedness based on conceptually decisions.

Table 1: Meme clusters and meme types.

| Meme Clusters | Meme Types |
|---|---|
| For GE: Anthropocentric Purposes | 1. Represents human progress, knowledge or technological advancement<br>2. Helps to improve world hunger crisis or aids the population increase<br>3. Improves human life, enhances human health<br>4. No other reliable alternatives to using non-human organisms |
| Against GE: Anthropocentric Purposes | 5. Processes are not natural<br>6. Economics (e.g., GE is too expensive)<br>7. Safety concerns, uncertainty of future effects, processes are risky |
| For GE: Biocentric Purposes | 8. Environmental/non-human species improvement |
| Against GE: Biocentric Purposes | 9. Cruelty to animals<br>10. Tampering with natural processes<br>11. Not necessary, waste of life, other alternatives |
| Other | 12. N/A or answer cannot be coded due to ambiguity |

Table 2: Frequency of memes occurring in individual meme types at each of three time samples.

| Meme Type/ Time Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day 2 (T1) | 3 | 0 | 7 | 1 | 0 | 1 | 5 | 2 | 9 | 2 | 1 | 1 | 32 |
| Day 10 (T2) | 6 | 1 | 7 | 1 | 1 | 1 | 2 | 1 | 10 | 3 | 1 | 1 | 35 |
| Day 16 (T3) | 3 | 5 | 6 | 0 | 1 | 1 | 7 | 1 | 6 | 2 | 5 | 1 | 38 |

Table 3: Categories of meme types found in each student's rationale at three time samples.

| Time/Student | Day 2 (T1) | Day 10 (T2) | Day 16 (T3) |
|---|---|---|---|
| Mark | 10 | 6 | 9 |
| Lisa | - | 1, 3, 4 | 3, 11 |
| Miranda | 3, 7, 12 | 5 | 3, 6 |
| Ebby | 3, 6, 7, 8 | 10 | 2, 7 |
| Patrick | - | - | 9 |
| Marshal | 4 | 12 | 12 |
| Ben | 3, 9 | 3, 9 | 9, 11 |

Table 4: Student's in-degree scores based on a ranking of like-mindedness.

| Ranking | Student (Day 10) | In-degree Score | Student (Day 16) | In-degree Score |
|---|---|---|---|---|
| 1 | Lisa | 6.1 | Natalie | 5.8 |
| 2 | Natalie | 6.6 | Thomas | 6.4 |
| 3 | Ben | 7.6 | Yasmin | 6.7 |
| 4 | Greg | 8.0 | Ebby | 7.1 |
| 5 | Janice | 8.5 | Norah | 7.2 |
| 6 | Ebby | 8.5 | Mark | 8.1 |
| 7 | Joel | 9.1 | Miranda | 8.4 |

| | | | |
|---|---|---|---|
| Natalie | 8, 9 | 1, 2, 9, 10 | 1, 2, 3, 9, 10, 10, 11 |
| Greg | 3, 3, 9 | 1, 1, 3, 11 | 1, 3, 11 |
| Sandy | 3 | 3 | 1, 2 |
| Norah | 1, 3, 9 | 9, 9 | 2, 3, 7, 7 |
| Yasmin | 9 | 3, 3, 7, 9 | 3, 9 |
| Annie | 7, 7, 7, 9 | 3, 9, 10 | 7, 8 |
| Janice | 9, 10 | 7, 9 | 5, 9 |
| Joel | 1 | 1, 8, 9 | 7 |
| Avery | 1, 9 | 10 | 7, 11 |
| Thomas | 9 | 1, 9 | 2, 7 |
| Saul | 11 | - | - |

| | | | | |
|---|---|---|---|---|
| 8 | Thomas | 9.1 | Annie | 8.5 |
| 9 | Marshall | 9.2 | Lisa | 8.5 |
| 10 | Norah | 9.4 | Janice | 8.6 |
| 11 | Yasmin | 9.8 | Ben | 9.6 |
| 12 | Sandy | 11 | Joel | 9.6 |
| 13 | Annie | 11 | Patrick | 9.8 |
| 14 | Miranda | 11 | Saul | 10 |
| 15 | Patrick | 12 | Avery | 11 |
| 16 | Saul | 13 | Sandy | 13 |
| 17 | Avery | 13 | Marshall | 13 |
| 18 | Mark | 13 | Greg | 13 |

## ii. Influences of Friendship.

Data analyzed on who students selected as the most like-minded also provide evidence of memetic mechanisms influencing group dynamics. This data is summarized in Table 5. On Day 10 (T2), the top line of the table shows that Natalie who has a rating of 0 selects Lisa and Ben who also have a rating of 0. Through researcher observations and informal discussions with students and corroborated by Ms. Saunders in interviews, student friendship clusters within the class were determined. At T2, Table 5 shows that 62% of students selected their first choice for like-mindedness as someone in their friendship cluster. In roughly half of the cases, student ratings were dissimilar and three out of the thirteen students had one meme in common. At T3 that percentage dropped to 22% where three out of the four students had the same ratings and three out of the four students had one meme in common.

Table 5: Student selections of most like-minded others who are part of their friendship cluster.

| **Day 10 (T2)** | **Day 16 (T3)** |
|---|---|
| Natalie (0) → Lisa (0), Ben (0) | Greg (+2) → Marshall (+4) |
| Sandy (+5) → Janice (0) | Yasmin (0) → Miranda (0) |
| Ebby (-2) → Janice (0) | Miranda (0) → Yasmin (0) |
| Greg (+1) → Marshall (+3) | Patrick (-3) → Ben (-3) |
| Lisa (0) → Natalie (0) | |
| Marshall (+3) → Greg (+1) | |
| Janice (0) → Ebby (0) | |
| Norah (0) → Lisa (0) | |
| Yasmin (0) → Miranda (0) | |
| Miranda (0) → Yasmin (0) | |
| Sandy (0) → Ben (0) | |
| Ben (0) → Natalie (0) | |
| Totals 12/18 = 67% | Totals 4/18 = 22% |

In addition to the "do as the smart students do" social dynamic occurring at T2, it is hypothesized that another social bias mechanism, i.e., selecting on the basis of friendship, contributed to decision making at the group level. There is other evidence to support this hypothesis. During small group collaborative activities in the first half of the study, students were allowed to exercise free choice as to who they wanted to work with. At T2, generally, students chose to work within friendship clusters. However, during the period prior to T3, a number of students indicated a preference to be assigned to groups. There are several plausible explanations as to why the dynamic shifted. One reason may have been that similar to the first social mechanism, just until after T2, students had difficulties grasping the concepts and felt more comfortable discussing ideas with students who they had an established social connection or positive identity, mitigating the possible negative judgments they may perceive. As students gained more confidence in their understanding, this identity bias was displaced by a more evidence-based content-specific bias that may have been a direct impact of the learning events embedded in the complex systems heuristic. As greater volumes of information entered into the cognitive system, where students cycled through both individual and group level metacognitive processing in conjunction with discursive activities in which students were required to publicly display their knowledge, an important conceptual feedback loop was established. This feedback loop may have served as a selection mechanism that, influenced greater variability in decision-making.

## iii. Meme-Coupling Influences.

Table 3 shows that at T1, in their written rationales, students most often selected memes in the meme type category of 'Cruelty to Animals' (9). Where there is more than one meme represented, this meme type was most often coupled (44% of the time) with memes from the categories of 'Improves human life, enhances human health' (3) and 'Represents human progress, knowledge or technological advancement' (1). The curricular materials during this phase of the study, in fact, focused on genetic engineering technologies such as cloning and xenotransplantation that required students to examine their beliefs about the value of non-human animal species relative to human life. This result can perhaps be viewed as the emergence of ambivalence, which were also evident anecdotally in verbal discussions between students. This ambivalence may have been manifested through equal consideration of both sides of the issue that forced students to take a neutral position. Furthermore, at T2, this coupling effect increased in frequency to 66%. While statistical claims based strictly on the numbers cannot be made, potentially significant cognitive memetic mechanisms at play can be explored through examination of student subgroup rationales.

In a previous section, data that illustrated a social mechanism of 'do as the smart students do' was suggested to account for differences in like-mindedness selections between T2 and T3. If at T2 the class was generally imitating the high academic status students then it is reasonable to conclude that reasoning inherent in explanations of the smart students would be mimicked. At T1 three of the four rationales that represented the meme coupling in the categories of 1, 3 and 9 were posited by Ben, Natalie and Greg. And either coincidentally or not, the number of meme coupling instances of this type increased at T2. Both Yasmin and Thomas are among the group that employed this potential mimicking strategy. At T2, the high status students continue to take neutral stances on the issue. However at T3, there appears to be an interesting shift. However, Ben and Greg change their neutral stances to negative (against genetic engineering) and positive (for genetic engineering) respectively. It is suggested that the meme coupling effect resulting in the evolution of the neutral stance created a strong selection force that actively selected against more parochial views that may have influenced the drastic drop in rankings for Ben and Greg at T3. Furthermore, as previously discussed, at T3, Thomas moves to the second position in the like-mindedness ranking where his rationale reflected concerns in the curricular focus at the time (crop farming). His selections included memes in the meme type categories of 'Helps to improve world hunger crisis or aids the population increase' (2) and 'Safety concerns, uncertainty of future effects, processes are risky' (7) resulting in a neutral stance. Tables 2 and 3 show increases in the frequencies of memes occurring in these categories at T3 and also demonstrate that when they occurred they were most often (38% of the time) coupled with each other. Ebby and Norah, ranked 4 and 5 respectively, also presented rationales that included this meme-coupling. This result provides additional evidence supporting the meme-coupling claim advanced here.

## Implications for Education

Within the science education literature, argumentation has been identified as a pedagogical strategy that could improve practices and understanding about socio-scientific issues. While the argumentation research has been focused on demonstrating how students reason with or without the practice of argumentation, few studies have been undertaken to reveal why difficulties in reasoning exist. It has been shown that the study of memes and memetic processes can provide potential insights about several memetic influences that appear to exert differential affects on what ideas are salient in the learning system of a classroom when studying a complex socio-scientific issue. When the classroom is viewed as a group of interacting agents, the complex network of relationships formed give rise to behaviors that can evolve over time. Within this complex system, this study provides some evidence to show that memes and memetic processes can have the potential to provide information about how the system is performing. The study of memetic processes can allow teachers to gain a better understanding about why students make decisions before and during an intervention (e.g., influences of friendship). After the intervention, it can also potentially allow teachers to understand how decisions are constructed, and what ideas are selected or not (e.g., meme-coupling). An additional advantage along this line of thinking is that it attends to the social and intellectual factors that impact our ideas. These are the components that need coordinated attention if students are to develop their ideas about socio-scientific issues that are of central importance in our society.

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