Teaching Tip
Managing Software Engineering Student Teams Using Pellerin's 4-D System

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ABSTRACT

In this article, we discuss the use of Pellerin's Four Dimension Leadership System (4-D) as a way to manage teams in a classroom setting. Over a 5-year period, we used a modified version of the 4-D model to manage teams within a senior level Software Engineering capstone course. We found that this approach for team management in a classroom setting led to qualitatively fewer incidents of teams unable to effectively work together, better projects, and greater group cohesion. In this article, we discuss our experience using the 4-D System, which was not originally designed for use in the classroom. We find our modified version of the 4-D System to be viable in a classroom setting and provide the reader with everything needed to implement 4-D in his or her own course.

Keywords: Team management, Groups, Pellerin's 4-D system

1. INTRODUCTION

The ability to work effectively in a team is an essential skill for computer science graduates. The accreditation body ABET listed the "ability to function effectively on teams to accomplish a common goal" as a required student outcome objective (ABET, 2014). Yet, building successful teams is not intuitive. Facilitating a team-building educational experience to introduce the benefits and skills needed for successful teams can be challenging. A limited schedule of course terms further complicates facilitating this experience. In recognizing the benefits of teamwork, both business and academic professionals have researched various ways to better develop more productive team collaboration. In this article, we discuss our use of Pellerin's Four Dimension Leadership System (4-D) as a way to manage teams in a classroom setting. We found that this approach for team management in a classroom setting led to qualitatively fewer incidents, better projects, and greater group cohesion.

The 4-D System is a team building process developed to improve communication and effectiveness among technical teams. Charles Pellerin, author of the 4-D System, was a Director of Astrophysics at NASA and discovered the importance of personality traits and their influence on well performing teams through the infamous failure of the Hubble telescope mirror (Pellerin, 2009). NASA attributed the Hubble incident to a leadership failure. Pellerin conducted his own extensive analysis on the problems related to the Hubble incident in the years that followed. His investigations led to proposing possible solutions or alternatives to team management. His particular focus was on team building with scientists, engineers, and computer scientists who notoriously resist traditional "touchy-feely" methods. The result of this work was the development of the 4-D team-building model (Pellerin, 2009). The 4-D process has boosted the performance of large-scale team projects including complex NASA project teams. For example, Pellerin estimates that execution of the 4-D assessment for a NASA team had a cost of $60 per employee per year with a possible increase in productivity of up to $40,000 per employee per year (Pellerin, 2009).

Our software engineering capstone course involves a large two-semester team based project. Starting in 2009, we have used the 4-D System in this course. The decision to use the 4-D System came after years of the instructor observing incidents of teams being unable to work together effectively. Typically, the incidents occurred within the teams as the due date for projects approached. Due dates are particularly stressful because the project concludes in the spring which serves as the graduation semester for nearly all students. The 4-D System combines both individual personality traits with an understanding of the task characteristics of software engineering. In addition, it includes periodic assessments to provide feedback at both the team and individual levels. Periodic assessment also allows the opportunity for changes in the style of team dynamics as the project progresses. A

single instructor has been responsible for this course both before and after the decision to use the 4-D System. This offers a unique and consistent insight into the benefits and drawbacks of 4-D.

2. BACKGROUND

Social science has studied the characteristics of team interaction and development for many years. Software development teams and projects have applied findings from social science research. Wiesche and Krcmar presented a structured literature review of this research and its impact on software development performance (Wiesche and Krcmar, 2014). In reviewing literature from computer science, they considered both personality models and software project management tasks. We look at the top four psychological models applied in the literature investigating software development as suggested by Wiesche and Krcmar.

The first three models focus on individual personality traits, while the last focuses on the task characteristics of software development. First is the Myers-Briggs Types Indicator model (Bradley and Hebert, 1997). This is the most prevalent theoretical model applied to computer scientists' personality research and is based on the Jungian personality dimensions model. Yet, a major flaw of this model is the underlying assumption that the types are mutually exclusive to one another. A second model, the Big Five Personality Dimensions Model (Goldberg, 1990) consists of five traits considered prominent and that are understood to be temporally stable and cross-situational. Similarly, the Five Factor Model (McCrae, 1992) is a variation of the Big Five Personality Dimensions model. It differs by including causation to the five traits. Researchers have used these models to research both individual and team subjects, however, Weische and Krcmar conclude that the various studies using these models found contradictory results. The fourth model suggested by Weiche and Krcmar is the Job Characteristic Model (Hackman and Oldham, 1975) which suggests there is relationship between the perception of different jobs characteristics and job outcomes.

There are various techniques for building successful software project teams (Ellis et al., 2008; Gorla and Lam, 2004; Pieterse, Kourie, and Sonnekus, 2006; Wiesche and Krcmar, 2014) as well as evaluating how to develop team work and team building effectively in classes (Ikonen and Kurhila, 2009; Lingard and Barkataki, 2011). Our work continues this line of research by presenting our experience with the 4-D System for team work/team building. To the best of our knowledge, no other work has attempted to use the 4-D System in a software engineering course.

3. OUR MOTIVATION FOR THE 4-D SYSTEM

From the 2002-2003 academic year through 2007-2008, the Myers-Briggs Types Indicator model was the primary outside source for the lessons on team building (Bradley and Hebert, 1997). Within the span of those years, most of the reported problems in team dynamics were of unacceptable behavior about team members not doing their fair share of the work. Students did not communicate these complaints to the professor until late in the course in individualized end of course reports. Students usually tried to self-manage the dysfunctional team dynamics, often suffering in silence. However, on some occasions, students inappropriately expressed the tension from poor team dynamics. In the 2008-2009 academic year, a single incident stood out and served as the call to action. A team in the capstone course was struggling as the due date for the project approached. One of the team members started to become directive, dismissive of input, and critical of other team members' capabilities in an effort to gain control over the project. Another team member asserted that the team should take a different direction. Ultimately, the two team members' inability to understand and work with one another devolved their ability to continue to be a productive team. Eventually the group's internal failures became publically visible in another class that the students shared together as they waited for another professor to arrive. The students began an argument for control of the project and because of their inability to understand how each member could contribute in a meaningful way, they began shouting. When shouting failed to work the students resorted to obscenities. This continued to escalate until the other professor arrived and intervened. The other professor referred students back to the capstone course professor to discuss the situation with the students.

The capstone course professor called the entire team in and gave the students the option to vote to 'fire' any of the team members. Interestingly, the students decided not to fire either of the two team members in question. The professor then gave recommendations for the group to work with one another more effectively. The team did come together enough to finish the project; however, this behavior not only publically exhibited the team's internal failure but also adversely impacted those outside the team, class, and major.

This situation prompted the capstone instructor to search for better methods to use in covering team building during the two semesters. Based on previous experience, there was a need to provide students with a helpful vocabulary to more easily identify and talk about the problems of the group. This vocabulary should be non-accusing or offensive and would provide a common way for students to talk about behaviors occurring and solutions to them. Because the problems seemed to be intensified as the due dates approached, it would also be beneficial to have periodic checkpoints to report problems before they become major issues. That summer a potential solution presented itself in the form of a Facebook post about how NASA builds teams. We purchased and evaluated the book *How NASA Builds Teams* (Pellerin, 2009) for our capstone course. Like most models, the 4-D System model focuses on different personality traits at the start of the project. However, it also provides a means to evaluate the team cohesiveness and to propose necessary changes in team dynamics throughout the life of the project.

4. INTRODUCTION TO THE 4-D SYSTEM

4.1 4-D Leadership Styles

The 4-D System, like Myers Briggs, is inspired by the Jung theory of personality development (Pellerin, 2009). The basis of the 4-D System begins with categorizing key components of high-performance teams and effective leaders. To illustrate the key components of the 4-D System, the use of a

2x2 matrix (decision-making influences x information gathering) is helpful. In this matrix, the X-axis measures a decision making process/influence. The measure moves from "emotional decision makers" to "logical decision makers." The Y-axis reflects methods for how a leader gathers information. Pellerin considers two types of information gathered: what we sense empirically and what we intuit. Based on the criteria of this matrix outline, Pellerin developed the 4-D System of Leadership Styles, illustrated in Figure 1.

The four leadership styles are described by Pellerin as follows:

- **Cultivating**: This emotional and intuiting dimension suggests deep feelings of what could be. Leaders' actions in this dimension address people's need for feeling appreciated. Strengths exhibited by this personality style include deeply caring about people and creating strong loyalty.
- **Including**: This emotional and sensing dimension suggests emotional experiences in the present, the deepest of which come from relationships with other people: harmony, inclusion, and relationships. Thus, leaders' actions here address people's deep needs for inclusion in relationships. Leaders also bring integrity to relationships by rigorously keeping all their agreements. This style exhibits strength in team building, creating harmonious teams, and finding ways to work with difficult people.
- **Visioning**: This logical and intuiting dimension suggests thinking about all possible futures. People with this style strive for the impossible while acknowledging difficult realities. People who tend toward this leadership style are idea builders who are full of creative ideas and demand excellence.
- **Directing**: This logical and sensing dimension suggests taking action. For example, people of this style might take on organizing and directing others. People with a strong connection to this leadership style also tend to be system-builders who are disciplined using reliable processes.

To more easily reference the leadership styles, each is associated with a color: Cultivating is associated with the color green; Visioning with the color blue; Including with the color yellow; and Directing with the color orange. Different leadership styles are better suited for different stages in a typical software development project. For example, Pellerin argues that each project phase has tasks that are best complemented by different leadership styles. For example, a project manager would take cultivating personalities (people builders) and assign them human resources tasks while taking including personalities (team builders) and assign them with marketing tasks. Both also have strengths in working with large, complex teams. A project in the early phases of getting started would assign a visioning personality (idea builders) for its leader. Similarly, execution phases or late stages of a project require a directing personality (system builders), with a focus of getting it out the door.

The basis of the 4-D leadership model is that all four dimensions are necessary for effective team management,

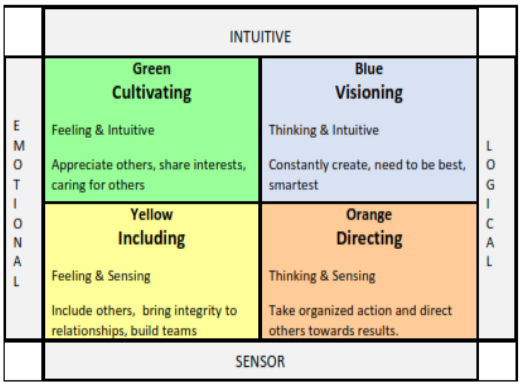

Figure 1. 4-D System Leadership Styles (Pellerin, 2009)

not necessarily just one. When one or more dimensions are omitted or lacking, team dynamics and team performance suffer. In project management and communications, there may be a necessary sequence of styles required: cultivating, including, visioning, and then directing. However, strong leanings among team members to one style or the other can result in conflicts. Instead of concentrating on a single perspective (1-D), the 4-D System challenges the teams and leaders to address the other three dimensions as well. A team member who is skewed too far in one quadrant (1-D leader) can fall into a failed state of leadership.

For example, the directing (orange) personality type excels in tasks that require management abilities such as planning, organizing, and controlling. A team consisting mostly of this personality type can create an environment where process and discipline are valued more than individual and team inclusion. The challenge for any personality type is incorporating the strengths of the other three dimensions. Continuing our example, the challenge for the directing (orange) personality is accommodating members with legitimate personal problems and addressing agendas that do not seem to directly support the end goal. To address this challenge, the 4-D System includes context/behavior management tools to assess and advise teams throughout the project timeline.

4.2 Continual Assessment/Improvement

A core notion of the 4-D System is the ability to influence behaviors through social contexts and drive a technical team's ability to perform. To that end, 4-D has developed tools to encourage focus toward the benefits and strengths of the other three dimensions. In order to identify a team's strengths and challenges as well as develop a more rounded 4-D leadership style, Pellerin developed assessment tools based on eight behavioral measurements that relate to the four dimensions of leadership styles.

For example, consider attention, which is one of the characteristics. D.J. Simons' video "Surprising Studies of Visual Awareness" demonstrates attention's influence on perception. Before watching the video, a facilitator instructs the viewer to count the number of times any of the players in a white shirt pass the ball. The instruction focuses attention on watching which player, and which colored shirt, is handling the ball. What the viewer often misses with this directed focusing is a person wearing a black gorilla suit

walking through the scene (Pellerin, 2009; Simons and Viscog Productions, 2008). The developers of the 4-D System propose that technically trained people tend to focus their attention intently on their own work and never see the 'social gorillas' that can disrupt team harmonics.

The management tool *AMBR* is designed to encourage intentional focus on the different personality or leadership strengths that may not be innate to a given personality/leadership type. In other words, for each dimension it is possible to consider behaviors that are inherent to that dimension. There is a specific focus on what a person with that dimension would pay *Attention* to, what sort of *Mindset* they have, the *Behavior* they exhibit, and the *Results* they realize. Here we consider what *AMBR* stands for and provide an example for the directing (orange) dimension:

- **Attention**: This personality type will naturally attend to the task and process.
- **Mindset**: This personality type will plan the work that needs to be done and following through with the plan.
- **Behavior**: This personality type executes their work with discipline and rigor.
- **Results**: This personality type achieves success through processes and consistency.

Using *AMBR* characteristics, Pellerin proposes behaviors that illustrate the strengths of each personality type. The presence and influence of behaviors from all four dimensions is used to assess the effectiveness of the team. The idea is to increase *AMBR* behaviors in all dimensions to increase team effectiveness.

The eight behaviors used to measure team and individual assessments include two behaviors identified in each of the four dimensions, see Figure 2. The cultivating (emotional and intuiting) behaviors address very fundamental human needs and reduce the cross-organization conflict which can be a source of team breakdown. Including behaviors instill trustworthiness and define what is expected. Visioning behaviors provide the foundation for creativity and help to direct team energy away from personality melodrama towards effective action. Directing behaviors avoid blaming and assess the perceived commitment level throughout the team.

Team dynamics inevitably suffer from miscommunication, stress, and other problems. Pellerin names four 'drama states' that teams can experience when these problems are not properly handled:

- **Victim**: "There is nothing I can do."
- **Rescuer**: "I'll do it." (when I should not)
- **Rationalization**: "It really doesn't matter."
- **Blamer**: "It's your fault!"

By discussing the possibility of these problem states before they occur, students may then potentially recognize unwanted behaviors in both themselves and the team. The discussion also gives students a vocabulary to talk about the tensions within the team. Pellerin also offers techniques to escape the problematic behavior, which often follows the drama state, before the situation escalates.

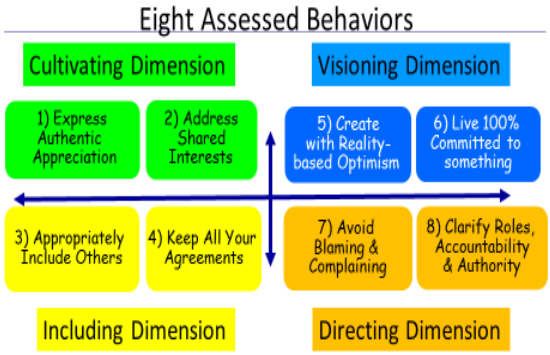

Figure 2. Assessed Behaviors (Pellerin, 2009).

The 4-D System includes two assessments that require individuals to rate how their team is performing with respect to each of these eight behaviors. The first assessment is broken down into team and/or individual development assessments questionnaires. The second consists of context-shifting worksheets, which address ad-hoc problems in team management. We did not use the context-shifting worksheets in our classroom setting and therefore do not discuss them. However, we do encourage readers to consider whether these context-shifting worksheets are appropriate for their own courses.

The team and/or individual development assessments questionnaire requires the team to rate their team on each of these eight behaviors. The assessments can compare the results of the individual and similar peer team data against one another. The results provide suggestions for re-setting the teams focus if necessary. This in turn should improve team performance. The 4-D System provides comprehensive guidance for this corrective action.

Team assessment is repeated throughout the project, usually every 6 to 12 months with the goal of identifying and measuring behaviors. Assessments document both individual experiences as well as team experiences. By providing a common vocabulary to discuss teams' social context, assessments provide focus on team behaviors and support collaborative discussions to drive behavioral change. Unfortunately, the assessments were originally written to address larger team projects over a longer period of time. For this reason, we had to modify the assessment to work in a shorter two course sequence.

5. USING THE 4-D SYSTEM IN A CAPSTONE COURSE

For the past five years we have been using the 4-D team building/management system in our capstone Software Engineering course. This course is a two semester service learning course that serves as a capstone for three different categories of students: computer science, information systems, and digital design students. It is worth mentioning that the digital design students also participate in a separate and more specific capstone experience that lasts a single semester.

The course emphasizes the software development process. Students are required to work in teams to provide solutions to real-world projects. Students in the course work on a service project from the local community non-profits or other university units. Examples of projects include web-page/database solutions for scheduling tutoring sessions for the Academic Success Center and University Writing Center. Students engage in requirements gathering, design, implementation, and testing of these projects. They also study the basic principles of structured systems analysis and software requirements specification by working with the project sponsors. Furthermore, students design data flow diagrams, perform object-oriented analysis, and practice using current charting techniques when creating the specification documents. They then use these documents as a basis for the development, testing, and implementation of the software system.

During the fall semester, on the first day of class the instructor announces projects to students. During the second class, the instructor introduces students to the 4-D System. Each student takes the test Pellerin developed which determines the personality color (Pellerin, 2009). Students then discuss the results in class. Because each personality type (color) is associated with both positive and negative behaviors, it is possible for the instructor to discuss all types of behaviors in a non-threatening, non-blaming manner. The instructor also uses his or her own personality color to explain behaviors that are helpful to a team and those that would not be helpful. As a way of engaging students and spurring discussions, the instructor sometimes asks students to wear a tag with their own personality type's associated color.

Having students take the 4-D personality assessment early in the course allows the instructor to use the results as one factor in setting up the teams. The instructor examines each student's background, skills, interests, and personality types in an attempt to ensure each team has at least one student who excels in programming, is innovative, and is skilled in writing. Because the class contains a mix of computer science, information systems, and digital design students, it is easy to come close to having a mix of skills on each team. This also means there is usually a mix of personality types to spread throughout the teams.

The fourth or fifth class is typically devoted to assigning the teams to their projects and discussing Pellerin's observations of the effect of personality on how well the team works together. Additionally, we discuss how this directly affects the success of the project. The advantage to using Pellerin's system is that the instructor outlines both strengths and the weaknesses inherent in each color type. This information is used very effectively in the classroom because every student is made aware of the benefits they bring to a team and the problems that they may cause the team. Problems can be discussed in a way that emphasizes how every personality type can be the source of problems, not just the stereotypical ones.

During the course of the year, the instructor reviews the team experience and the problems to avoid in class. As Pellerin suggests, students take the assessment on a regular basis. However, in order to measure how well the teams work together, the 4-D System uses a more extensive assessment given to large teams of professionals often working on long-term projects. Because this test is not necessarily appropriate for college student teams, Dr. Frank Martin, a 4-D consultant and former Director of Astrophysics at NASA, designed for us a modified evaluation instrument, found in Appendix 1. This modified instrument is a subset of the Team Development Assessment used by the 4-D System. Modification of this instrument made it more suitable to a classroom setting. The instrument uses a Likert scale ranging from 1 to 10 to measure each dimension. Additionally, it determines how teams are doing relative to each of the eight behaviors. In order to compute a score, the Likert responses in each dimension are added together and then averaged across the team. There is one exception: item number 7's scale should be inverted for calculation purposes. In other words, always being in a blaming state (10 on the Likert) would be undesirable and should not positively affect the score for that dimension. Therefore, a score of 10 would become a score of 1, a score of 9 a score of 2, and so on. With this data, an instructor can easily spot team issues and intervene much earlier before the problems get out of hand. We give the assessment twice during the spring semester because this is where the teams typically start to have issues. We do note that over a multi-year span there have been exceptions, for example, during years where snow days prohibited the use of class time for this activity. While it would be possible to increase the frequency, there may be a point of diminishing returns for the use of class time to administer this assessment.

6. DISCUSSION

To understand the impact 4-D had, we examine the chronology of the Software Engineering capstone course and the team problems encountered before and after implementing the 4-D System. In 2009-2010, we first started using the 4-D System for team building. In the class, we discuss the 4-D personality model and how students can use their strengths and modify their weaknesses to build a team that works well as a team. We started to administer the modified 4-D System assessment instrument (see Appendix 1) in 2010-2011 at the end of both the first and second semester. Our experience with the 4-D System assessment from the 2009-2010 academic year through 2013-2015 has been very positive and without incident. In the 2011-2012 academic year, the 4-D System was able to help drive teams starting to experience problems. The student teams included several students with strong feelings about how to run their respective projects. This class had a number of directing students (orange color type) which may have been a contributing factor. Even then, however, team dynamics and the end of semester reports did not reveal any difficult encounters. With the 4-D System, students were able to better understand their team and work with their team members in more meaningful and constructive ways.

In our experience, we noticed that before using the 4-D System, there was no formal mechanism for the students to discuss problems between team members. There was no common vocabulary for the students to express concern for problems within the team. Additionally, problems in the team's dynamics escalated before it was possible to direct

the team to a more productive resolution. Disagreements tended to fester through the semester, coming to a head when projects came due.

The 4-D System provided students the ability to negotiate through various stages of the project. Furthermore, students were able to relate each stage to a leadership style that was appropriate, for example, matching a visioning leader at the start of a project and a directing leader as the project progressed. The assessment questionnaire provided a vehicle to initiate a constructive conversation about the positive and negative aspects of team performance at times throughout the semester. Even when the assessment test scores indicated a higher level of team disunity and concern at the end of the second semester, we observed that the teams continued to function smoothly and efficiently.

Finally, the use of the 4-D System extends beyond just the classroom. For example, a student in the Fall 2010/Spring 2011 class emailed to discuss an internship experience. This student had an internship with other students from another university within the context of a team-based project. One member of his team had difficulty working with others. The student used the skills he learned with the 4-D System that allowed him to work through the situation and ultimately resulted in a successful outcome for himself and his team.

7. LIMITATIONS

To the authors' knowledge, no other universities have used the 4-D System in the classroom setting. While this makes the use of 4-D in a classroom setting novel, it also limits the ability to generalize findings. For example, other institutions may have students with different expectations regarding group projects. Furthermore, students may form their expectations based on their prior experiences with group projects in other classes that our institution does not provide. In addition, the use of 4-D within our own institution has been limited to a single set of courses which have been led by a single instructor. The introduction of other instructors may negatively or positively affect the outcomes we have observed.

There is also the possibility that other factors may have contributed to the perceived success of the 4-D system in our classroom setting. For example, students taught after the adoption of 4-D classes may have represented a less aggressive or more normal population of students. In addition, it is possible that the students perceived that the instructor's expectations were that no conflict should arise. Students therefore may have resolved differences themselves without resorting to involving the course instructor.

8. CONCLUSION

The 4-D System team-building tool is viable for classroom projects. The advantage to using Pellerin's system is that the system outlines both strengths and weakness inherent in each personality (color) type. Instructors can use the information effectively in the classroom because every student is aware of the benefits they bring to a team and the problems that they may cause to arise. When interpersonal problematic situations arise, the instructor can discuss them in a way that emphasizes how every personality type can be the source of problems as well as helping students to work towards a solution.

The benefit of using the 4-D System in the classroom has been that there have been no severe team problems during the time this system has been used to teach team building. While problems have arisen, team members have largely dealt with them on their own. Before using the 4-D System to cover team building, there were regular problems that teams could not handle. This caused teams to break down, particularly in cases where no one would approach the instructor. Sometimes these breakdowns even surfaced publicly causing issues in other faculty classes. Additionally, most problems did not surface until the end of the semester when it was largely too late to make a meaningful change. While using the 4-D System for over five years, none of these major problems has occurred even when team makeup was conducive to conflict, for example, by having a large makeup of directing personalities.

Finally, the 4-D System was created for large, long-term projects that cause it to not be directly suitable for semester long projects. Thus, modification to the tools was required to better suit the system for semester courses. As future work, researchers could develop an even more concise design of the 4-D team-building model to better fit it to the academic calendar. This model could include a more formal action response system for students to pinpoint and address team problems. Additionally, more research needs to be conducted to validate its effectiveness both within and outside the classroom.

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APPENDIX 1 - Modified 4-D Instrument

Team Assessment Questions

The following questions are intended to evaluate the effectiveness of your team. Note that the results of this evaluation will NOT be a part of your grade. The answers to these questions are intended to improve the effectiveness of your team.

Answer each of the following questions using a sale of 1-10 where a 1 indicates “never” and a 10 indicates “always”. You are to answer based on your observations of the behaviors of your team.

Cultivating Dimension:

1. Are they expressing appropriate appreciation?
2. Do they have shared interest around the project?

Including Dimension:

3. Are they appropriately including others including each other?
4. Are they keeping all of their agreements with each other and with the team?

Visioning Dimension:

5. Are they acknowledging the "cold hard truth" about their project and applying reality-based optimism?
6. Are they committed to the project?

Directing Dimension:

7. Are they in any of the 4 drama states (Victim, Rescuer, Rationalizer or Blamer)
8. Are the roles, accountability and authority clear around the project?

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