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Agency Name:	National Science Foundation
Agency Tracking Number:	**2145027**
Organization:	
NSF Program:	Combinatorics
PI/PD:	Williams, Nathan
Application Title:	CAREER: Dynamical Algebraic Combinatorics

Review 1

Rating:

Multiple Rating: (Very Good/Good)

Review:

Summary

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to intellectual merit.

IM Rating: V/G

The main aim of the PI is to further the field Dynamical Algebraic Combinatorics (DAC), which was launched in 2012 by the PI and coauthor J. Striker. This will include (1) developing their theory of ``independent polytopes", (2) studying the connections to braid group actions on quantum groups, and (3) resolving related problems on cluster algebras.

This proposal is very well organized, and although there are a few typos, it is clearly written overall and has helpful illustrations. The PI has the background to address the projects that they proposed, but it is not clear that the projects are ambitious enough to merit a five year grant.

The projects for goal (1) are Problems 1-3, of which Problem 2 is the most ambitious (on extending the theory of independence posets to general digraphs). But there was not much of a strategy presented for Problem 2. Problem 1 is a bit vague, and Problem 3 is narrow.

The projects for goal (2) are Problems 4 and 5, both pertaining to encoding ``piecewise-linear toggles" algebraically. Piecewise-linear toggles were discussed in Section 2.2, but the motivation for this construction could be made clearer there. In any case, the proposed projects provide an interesting connection between symmetries of quantum groups and DAC; more discussion of how the PI plans to address these problems is needed.

The last collection of problems, Problems 6-8, are on goal (3). There may be a typo in Problem 6 as the goal is to show that there is a bijection from the set $\mathbb{N}^n$ to the set ``Assoc$_c^+(W) \times \mathbb{N}^n$". Moreover, it is not clear how the following example, Example 9, relates to Problem 6, nor is there a strategy presented to address this problem. Problems 7 and 8 are also on bijections with the set Assoc$_c(W)$ (and Assoc$_c^+(W)$) of a (positive) cluster complex attached to a finite Coxeter group W and Coxeter element c. There are tractable strategies presented for these problems, and these problems are motivated by the connection between clusters and nonnesting partitions.

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to broader impacts.

BI Rating: V/G

The broader impacts and (educational activities?) involve (1) supervising undergraduate research projects, (2) organizing conferences and workshops, (3) online textbooks and software in discrete mathematics, and (4) running a math circle. For (1), the PI stated that they have a ``substantial past experience in involving students and underrepresented students" in research. The PI does have a good track record of supervising a large group of undergraduate students in research, but there is no evidence that a significant portion of these students are members of underrepresented groups. Moreover, the phrasing of this claim is awkward. Although items (2), (3), and (4) are not as innovative as the other educational activities proposed by others in the grant competition, they are excellent contributions to the math community.

Please evaluate the strengths and
weaknesses of the proposal with respect to any additional solicitation-specific review criteria, if
applicable

Summary Statement

This proposal was #4 out of the 7 reviewed.

Review 2

Rating:

Multiple Rating: (Good/Fair)

Review:

Summary

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to intellectual merit.

IM Rating: G

The intellectual merit of the proposal is good, but not as strong as that of others I reviewed. The research projects are nice, but do not stand out in comparison to other proposals. A part of the proposed research builds on results from a paper by the PI and Striker from 2012 that has inspired a good deal of research.

Sometimes the exposition could have been better. For example, Problem 1 is rather vague and it is not clear what the motivation behind it is. Also I did not fully understand Figure 1. From the narrative I understand that the pairs (D,U) are tight orthogonal pairs, in particular there should be no edge between them. However the blue and yellow points in Figure 1 do not satisfy this condition.

The motivation behind Problem 2 is also not clear. Moreover, I did not understand the claim that the independence posets generalize Birkhoff's theorem. Isn't every acyclic digraph a poset?
In Figure 4, why is 110 a point in the poset although there is an arrow from 1 to 2?

The second project on braid group actions on quantum groups is interesting, but maybe somewhat narrow since it requires a minuscule vertex. In type A, all vertices are minuscule, but in all other Dynkin types a minuscule vertex is very special (and in type E8 there is none).

Problem 7 is about the number of clusters in a Dynkin type cluster algebra. This number is known as a generalized Catalan number. There is a uniform formula for this number but there is no uniform proof and the PI proposes to find one. The proposed approach is to solve another conjecture that was formulated by the PI in 2013. Given that eight years have passed, one may have some reservations here, but even if the approach works it would only give us a better understanding of a known result but not produce a striking new development.

The PI had prior NSF support in the form of a conference grant in 2018 which was used successfully at a conference for graduate students.

Note to PI - the publication dates are missing in the biographical sketch.

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to broader impacts.

BI Rating: V

The broader impacts are very good. The PI has mentored undergraduate research during six summers and has directed three honors theses. He is advising two PhD students. He has organized workshops at AIM and BIRS and several AMS special sessions. The PI is an editor for Annals of Combinatorics.

The PI participated as a mathematical consultant in a televised report on the NCAA basketball bracket. He also has been active in outreach events and math competitions.

He also is interested in improving mathematical interaction in an online setting. He has presented an interactive poster at an online conference in 2020.

Please evaluate the strengths and
weaknesses of the proposal with respect to any additional solicitation-specific review criteria, if
applicable

The educational component does not really exist in the sense that there is no separate section for it. Also in the budget justification, I did not find funds reserved for educational activities beyond graduate student support. Instead the PI lists activities in the broader impact section, but most of them took place in the past. Here is what I found for future projects.

The PI proposes to use his new approach to online posters as a new way to interact with students in the classroom or online. This seems an exciting new project.
He will organize a yearly online workshop for undergraduates and early graduates. Unfortunately, the proposal does not contain any details about these workshops.
The PI further proposes to create an online library (in Sage) of combinatorially relevant graphs and their independent sets.
He will also organize math circles at his institution. It is not clear from the proposal if the participants will be undergraduates, high schoolers or even younger mathematicians.

Summary Statement

The research part is good but not as strong as other proposals. I don't know what to say about the educational component. It seems like the PI was not aware that the proposal should contain one. Even without it, the broader impacts are very good.

I rank this proposal in the lower third of the proposals I have reviewed.

Review 3

Rating:

Good

Review:

Summary

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to intellectual merit.

IM rating: G

The PI is an enthusiastic evangelist for Dynamical Algebraic Combinatorics. While this area of study seems promising, I was unable to get much out of the specific plans described in the proposal. The statements of Problems 1 and 2 are vague. Problem 3, regarding the graph top^{(m)}(G), is more detailed and would clearly represent progress in the field, though I did not get a clear sense that the PI has a plan to attack this problem. I had similar concerns on Projects 4-8. There was a strategy proposed for Problem 7, but it was based on the PI's PhD thesis from 2013, and it was not clear whether any new ideas had come to light in the intervening 8 years.

In the context of the five review elements, please
evaluate the strengths and weaknesses of the proposal with respect to broader impacts.

BI rating: G

The PI plans to create a JavaScript textbook on discrete mathematics, drawing from his experience with interactive FPSAC posters. I looked at his poster and thought that it worked really well. I'm less convinced that it would work well as a textbook.

He also plans to organize an annual on-line workshop and to organize a Math Circle at UTD. The Math Circle would be quite valuable, though it would take much more than a CAREER grant to get it off the ground.

Please evaluate the strengths and
weaknesses of the proposal with respect to any additional solicitation-specific review criteria, if
applicable

Summary Statement

This project is centered on examples of group actions on various sets that arise naturally in algebraic combinatorics, such as rowmotion on the set of order ideals of a poset, and promotion on the set of semi standard tableaux of a given shape. The main educational activity is to create an interactive textbook with tools to illustrate these group actions.