STATEMENT OF RESEARCH

I am a teaching postdoctoral fellow at Dixie State University's (DSU) Physical Sciences Department. My current and past research has been centered on small molecule synthesis for medicinal applications. Even though my training and specialization is in organic chemistry, during my postdoctoral experience, I have branched into chemical education in design, implementation and evaluation of flash card games as learning tools for classroom use.

Past Research: I was encouraged early on in my sophomore year of college to get involved in undergraduate research. I worked under Dr. Marvin Miller in a synthetic organic chemistry laboratory that focused on synthesizing imidazole-based small molecule antibiotics targeting multi-drug resistant tuberculosis via EDC coupling reactions.

For my graduate work, under Dr. Suazette Mooring, I designed, synthesized, and analyzed small molecule modulators for the chemokine receptor CXCR4. CXCR4 selectively binds to chemokine ligand CXCL12[1-2] and this interaction triggers necessary physiological functions as well as disease related pathways like cancer metastasis and inflammation.[3-6] When the interaction between CXCR4 and CXCL12 is blocked, metastatic cancer cells, which overexpress CXCR4,[7] are unable to migrate to the bone marrow or other places in the body to take root. Blocking this interaction also reduces inflammation caused by auto-immune diseases or external irritants.[8-11] AMD3100 was the first CXCR4 antagonist to become FDA approved; however, it was only approved for one time use because it was cardiotoxic and had poor oral bioavailability.[12] Many derivatives of AMD3100, a class of molecules is called p-xylyl-enediamines, were synthesized and reduced cardiotoxicity by using non-chelating sidechains.[13] Unfortunately they retained similar oral bioavailability problems.[14] In using heterocyclic aromatic rings as the core of the scaffold instead of the benzene in the p-xylyl-enediamine family, the partition coefficient of the compound is lowered and can increase its oral bioavailability according to the Lipinski rules.[15]

The purpose of my work was to create a structure activity relationship (SAR) library of p-xylyl-enediamine derivatives where a heterocyclic aromatic ring was used instead of the traditional benzene ring. I have synthesized, purified and characterized over one hundred 2,5-furan-based, 3,4-thiophene-based, 2,5-pyrazine-based and 2,6-pyridine-based[16-18] p-xylyl-enediamine derivatives using reductive amination reactions. These compounds were tested in assays for binding efficiency to CXCR4, metastatic cell migration prevention and inflammation reduction by our collaborators at Emory University. I also analyzed the compounds *in silico* using AutoDock, AutoDock Vina and Schrodinger to help draw connections as to which substituents contributed most to activity and how to design more compounds that maximize activity

Current Research: My current work includes two projects from two different disciplines: Small Molecule Synthesis and Chemical Education.

Small Molecule Synthesis*:* My current project that I am currently working on with undergraduate students is a branch from my previous work in developing a heterocyclic aromatic-based SAR library of p-xylyl-enediamine derivatives. This work involves using a novel heterocyclic aromatic core: 2,4-pyridine. This project is still in its infancy and my students and I are currently synthesizing our starting material using the 2,4-pyridine core to prepare it for our reductive amination reactions. Due to some limitations in waste disposal at our current university, we are attempting some green-er synthesis alternatives and are experimenting with solvents in which to conduct our preliminary oxidation and reduction reactions to synthesize the aldehyde form of our 2,4-pyridine core.

Chemical Education: My current work involves design and implementation of card games as in-class tools to build fluency in chemical concepts in organic chemistry and GOB (general, organic, biochemistry course for pre-nursing students) classes. To date, I have created, play-tested, and implemented three card games in my classroom. In order to distribute these games to collaborators in Utah, I was required to register as an LLC; therefore, all of the games discussed below can be found at http://www.bigmagnetgames.com. The main three games are listed below:

- *Barely Functional* is a card game to help students learn and practice identifying and grouping functional groups.
- *Chaperones* is a collaborative card game to help students identify and utilize their understanding of intermolecular forces to fold a protein before the prion (played by the teacher) misfolds it.

- *Songbird* is a two-person call-and-response game that relies on students' deductive skills to draw the appropriate resonance structure.

Now that I have three working games, I am in the process of undergoing university IRB training and I am currently drafting up plans and tools for a preliminary, quantitative efficacy study to see if these games aid in student's acquisition of knowledge on the subject matter.

Future Directions:

Small Molecule Synthesis: My future plans include continuing to synthesize a library of the 2,4-pyridine analogues with undergraduate students using reductive amination. My former collaborators at Emory have expressed interest in continuing our collaboration with the new pyridine core to screen for activity and add a new core to the SAR library. In addition to continuing the SAR library with this new core, there are several more heterocyclic aromatic cores not yet reported in the literature that I would like to attempt to synthesize (the starting materials are not commercially available) to see if we could attempt a few more branches with the new cores. These would include asymmetrical heterocyclic aromatic rings which have not yet been synthesized and screened for activity in the literature. These would include: 3,4-furan, a 2,4-furan and a 2,3-pyrazine and a 2,3-pyridine. My previous collaborators have expressed interest in testing the compounds in our standard assays; however, I would be open to considering in-house collaborations if available at the University to screen these small molecules. The reductive amination reactions are performed and purified in standard laboratory glassware. Special materials that might be needed in this process would include access to nitrogen gas (fillable by balloon), chromatography columns and silica. In order to characterize the products produced, access to a 400 MHZ NMR, and an accurate mass spectrometer are standard for publication.

Chemical Education: Literature suggests that incorporation of active learning strategies lead to better student achievement, but there is no clear consensus on the efficacy of educational games.[19] There is a plethora of descriptive communications in the literature about chemistry games and activities that can be used in class; however, assessment of game efficacy is not as prominent in the literature. I hope to begin addressing some of the loose ends in the literature by assessing my current games so they can more effectively be used as tools by instructors and students. My first project involves assessing student's attitudes towards the card games, the subject matter that the games are designed to help them practice, and assessment of the game's efficacy in helping students acquire knowledge. The student attitudes will be probed issuing a pre-, post- and a delayed post-survey using a Likert scale to obtain quantitative data. Students would also be given a pre-, post- and delayed post-test on the content material to assess knowledge acquisition and retention. Each game would have a different set of surveys and tests; however, the resonance structure game is one that I am most curious to see the outcomes for. Depending on class sizes and the number of potential collaborators, data might need to be gathered over two or three semesters. From there, as an expansion, interviewing students to probe their impressions and experience playing the game would be a fun qualitative study.

I have a few other games in development that I would assess in similar fashion to the aforementioned games—however, my second main project would focus on creating a series of chemistry-based legacy games for students to use as study tools outside of the classroom. A legacy game is a game that uses certain mechanics that ensure that permanent changes are made to the physical game each time it is played—so that if someone wants to replay the game using the same physical materials, the game is fundamentally different from the first time it was played. The idea for creating a legacy game came from reading about gamification. Gamification is the process of adding game elements and mechanics to courses such as achievements or badges in order to help students become self-motivated learners and to help them have an engaged experience.[20] Current studies are inconclusive about the effectiveness of gamification in the classroom.[21] Even still, I asked: If I could award a badge for mastery over organic chemistry concepts, what type of questions and tasks would I assign to a student?

For each game in this legacy series, students will be guided to develop a robust learning tool or cheat sheet to use as they become acquainted with the subject material of a very specific topic in chemistry; however, as they play deeper into the game, they will be instructed to alter or destroy the learning tool, create a new one or rely on their own knowledge to progress. Current plans are for students to go through six rounds in the game, each focusing on a tier of Bloom's taxonomy[22] so that the game becomes harder to play, and the students have less tools to rely

on as they continue through the game. At the end of the game, the student's reward is that they've demonstrated mastery over the game's topic. Development of this game has been and will continue to be an iterative process, where we develop content and then go to students to playtest, get feedback and modify the game before going back to play testers. This is so that we can deliver the intended experience of the game. The game design process would yield to some interesting qualitative data that could be used to create other tools and other material on designing and playtesting chemistry education games as we will be going back and forth between students and collaborators to probe their impressions and frustrations with the developing game. At the end of the iterative process, the goal is to have a functional game that can then be used to help students attain mastery of a chemical concept, to which the research would change to assessing the effectiveness of such a tool in a quantitative way. This process would then repeat for each game in this legacy series on a select few topics where each takes a few years to complete. Topics that are currently in progress include: functional groups, resonance and electronegativity.

In order to complete these games and analyze them, a few materials are required: Primarily space where students can conduct and be interviewed would be necessary for quantitative studies. Computers equipped with SPSS or other statistical software would also be useful for interpreting data received from the quantitative studies. In addition not these things, the possibility of collaboration with my fellow colleagues would be necessary in order to build up a decent sample size of students.

In addition to the above projects, I am always interested in collaborating to help design new learning tools and activities for educators and students alike. My intention is to continue to develop games and tools to help students have a meaningful educational experience through play.

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