Table 1: a simple Activity-and-Experience Grid

	student activities				
science experiences	#1	#2	#3	#4	#5
A. design experiment	—	—	—	yes	yes
B. do experiment, make observations	yes	yes	—	—	yes
C. hypothetico-deductive reasoning	—	yes	yes	—	yes
D. invent theories	—	—	yes	—	yes

Table 2: Science Experiences, based on a model of 'Integrated Scientific Method'

	SCIENCE EXPERIENCES	science experiences are discussed in sections:
1a	• **PREPARATION** for content, process; backward-reaching, forward-reaching	2.71_{F} , $2.72_{B,F}$, 2.73_{B}
1b	• **POSING** of an *area* to study, and of *constraints* on a solution	$2.71_{A\text{-}D}$, $2.72_{B\text{-}E}$
1c	• **PROBING** pursuit: invent, evaluate, and execute probing-actions	$2.71_{B,D}$, 2.72_{F}
2a	SELECT an old theory (observations + retroductive logic +...)	2.51
2b	INVENT a new theory (observations + retroductive logic +...)	2.52-2.53
3a	DESIGN EXPERIMENT (find gaps, do thought experiments,...)	2.61-2.62 , 2.63_{A}
3b	DO EXPERIMENT, make OBSERVATIONS	2.11_{E}
4a	theories + system → PREDICTION (using "if-then" deductive logic)	2.11_{D} , $2.11_{B\text{-}C}$
4b	estimate degree-of-AGREEMENT, by comparing obs with T-predictions	2.12_{A} , 2.52
4c	estimate degree-of-CONTRAST, compare obs-vs-predn for T & alt-Ts	2.12_{B} , 2.61_{F}
4d	PREVIOUS agreement-and-contrast (empirical evaltn for previous expmts)	2.12_{C} , 2.52_{E}
5a	INTERNAL characteristics of Theory (check T's ontology, systematicity,...)	2.21-2.26
5b	EXTERNAL relations with other Ts (domain overlap, shared components)	2.27-2.28
6a	metaphysical & ideological	2.31_{B}
6b	psychological, practical, authority	$2.31_{A,C}$
7a	EVALUATION → "conclusion" Δ in T-status? retain revise reject	2.42
7b	• **PERSUASION** (of self, research group, or outsiders)	2.61_{G} , 2.71_{E} , $2.72_{C,F}$

abbreviations: obs = observations, T = theory, predn = prediction, alt = alternative, evaltn = evaluation, expmts = experiments, Δ = change

Table 3: Science Experiences during the "Black Box Model Revising" activities

	3.31$_A$ Black Box model-building	**3.31$_B$** Black Box conference	**3.31$_C$** Black Box model-revising
• **PREPARATION** for content, process; backward-reaching, forward-reaching	backward, NO ? forward, YES	forward: listen to others' ideas	backward: yes forward: yes
• **POSING** of an *area* to study, and of *constraints* on a	NO (area) yes (constraints)	NO yes	NO yes
• **PROBING** pursuit: invent, evaluate, and execute probing-actions	YES ! many decisions	YES for persuasion	YES
SELECT an old theory (observations + retroductive logic + ...)	yes, but old Ts are not sufficient	own model from first day	begin w own T or out-group T
INVENT a new theory (observations + retroductive logic + ...)	T-building and T-revision	is possible but is not expected	by revision of existing theory
DESIGN EXPERIMENT (find gaps, do thought experiments,...)	yes; eventually is guided by T	to support own or to challenge	yes
DO EXPERIMENT, make OBSERVATIONS	yes	to demonstrate,	yes
theories + system → PREDICTION (using "if-then" deductive logic)	usually done after experiment	as explanation, or as	yes
estimate degree-of-AGREEMENT, by comparing obs with T-predictions	yes	yes, this is important	yes
estimate degree-of-CONTRAST, compare obs-vs-predn for T & alt-Ts	competitive Ts of own group	compare own T with other	yes
PREVIOUS agreement-and-contrast (empirical evaltn for previous expmts)	as experiments accumulate	yes, all data is considered	yes, from all 3 days
INTERNAL characteristics of Theory (check T's ontology, systematicity,...)	ask "Is it possible?"	yes	yes
EXTERNAL relations with other Ts (domain overlap, shared components)	check w known physical laws	yes	yes
metaphysical & ideological	assumption of consistency	consistency	yes
psychological, practical, authority	relations with own group, Sue	relations w all students & Sue	yes
EVALUATION → "conclusion" Δ in T-status? retain revise reject	yes, through whole process	of own T and other Ts	to decide on a "final model"
• **PERSUASION** (of self, research group, or outsiders)	persuasion of self & groupers	persuasion of others, mainly	yes

abbreviations: obs = observations, T = theory, predn = prediction, alt = alternative, evaltn = evaluation, expmts = experiments, Δ = change; w = with

Table 4: Science Experiences during the "Genetics Phenomena" activities

	3.32$_A$ cookie analogy	**3.32$_B$** human variations	**3.32$_C$** human pedigrees
• **PREPARATION** for content, process; backward-reaching, forward-reaching	learn concepts and terms	learn concepts and terms	learn concepts and terms
• **POSING** of an *area* to study, and of *constraints* on a solution	— yes (questions)	— yes (questions)	— yes (questions)
• **PROBING** pursuit: invent, evaluate, and execute probing-actions	—	—	whether to interpret
SELECT an old theory (observations + retroductive logic + ...)	—	—	—
INVENT a new theory (observations + retroductive logic + ...)	—	—	finding patterns in the data
DESIGN EXPERIMENT (find gaps, do thought experiments,...)	variations on a basic recipe	—	—
DO EXPERIMENT, make OBSERVATIONS	bake cookies, examine them	make observations	(second-hand data is used)
theories + system → PREDICTION (using "if-then" deductive logic)	—	—	—
estimate degree-of-AGREEMENT, by comparing obs with T-predictions	—	—	—
estimate degree-of-CONTRAST, compare obs-vs-predn for T & alt-Ts	—	—	—
PREVIOUS agreement-and-contrast (empirical evaltn for previous expmts)	—	—	—
INTERNAL characteristics of Theory (check T's ontology, systematicity,...)	—	—	—
EXTERNAL relations with other Ts (domain overlap, shared components)	—	—	—
metaphysical & ideological	—	—	—
psychological, practical, authority	class bonding: milk & cookies!	more bonding	—
EVALUATION → "conclusion" Δ in T-status? retain revise reject delay	—	—	—
• **PERSUASION** (of self, research group, or outsiders)	—	—	—

abbreviations: obs = observations, T = theory, predn = prediction, alt = alternative, evaltn = evaluation, expmts = experiments, Δ = change; w = with

Table 5: Science Experiences during the "Initial Models" activities

	3.33$_A$ building a model of dominance	**3.33$_B$** building a model of meiosis	**3.33$_C$** GCK practicing and exam
• **PREPARATION** for content, process; backward-reaching, forward-reaching	preparation for model revising	preparation for model revising	preparation for model revising
• **POSING** of an *area* to study, and of *constraints* on a	NO yes	NO yes	NO yes
• **PROBING** pursuit: invent, evaluate, and execute probing-actions	minimal choices about	minimal choices about	yes, students decide actions
SELECT an old theory (observations + retroductive logic +...)	assumed to be not available	mitosis; but it is not adequate	yes, but there is only one option
INVENT a new theory (observations + retroductive logic +...)	yes, by guided construction	yes, by guided construction	retroduction only for system
DESIGN EXPERIMENT (find gaps, do thought experiments,...)	watch how an expert does it	field study? yes	yes, but within narrow limits
DO EXPERIMENT, make OBSERVATIONS	peas provided; classify &	field exprmts → observations	yes
theories + system → PREDICTION (using "if-then" deductive logic)	yes	yes	yes
estimate degree-of-AGREEMENT, by comparing obs with T-predictions	major factor in development	major factor in development	yes (no anomalies)
estimate degree-of-CONTRAST, compare obs-vs-predn for T & alt-Ts	"blending" T is a competitor	mitotic model is a competitor	not possible: no alternative
PREVIOUS agreement-and-contrast (empirical evaltn for previous expmts)	yes	yes	yes
INTERNAL characteristics of Theory (check T's ontology, systematicity,...)	yes in Mendel	yes	↑ understanding
EXTERNAL relations with other Ts (domain overlap, shared components)	this is not a major factor yet	yes; relations with	no; has been done already
metaphysical & ideological	assumption of consistency	consistency	sophisticated "consistency"
psychological, practical, authority	collaborations w Mendel,...	collaboration w group & class	social w group and w teacher
EVALUATION → "conclusion" Δ in T-status? retain revise reject	accept Mendel's model	accept meiotic model	no reason not to retain
• **PERSUASION** (of self, research group, or outsiders)	by empirical + authorities,...	by empirical + conceptual + ...	re: exp-system, using GCK,...

abbreviations: obs = observations, T = theory, predn = prediction, alt = alternative, evaltn = evaluation, expmts = experiments, Δ = change; w = with, exp = experimental

Table 6: Science Experiences during the "Genetics Model Revising" activities

	3.34$_A$: revising the existing model(s)	**3.34$_B$**: conference to discuss models that are invented
• **PREPARATION** for content, process; backward-reaching, forward-reaching	all preceding activities are to prepare for this	GCK work is a preparation for this
• **POSING** of an *area* to study, and of *constraints* on a solution	NO yes	NO yes (goal is persuasion)
• **PROBING** pursuit: invent, evaluate, and execute probing-actions	YES, many decisions about pursuit-actions	preliminary planning and quick improvisation
SELECT an old theory (observations + retroductive logic +...)	in Round 1, no options; later, students can choose	as starting point to show how new T was
INVENT a new theory (observations + retroductive logic +...)	this is the focal point of the entire course; YES	presented model usually does not need revising
DESIGN EXPERIMENT (find gaps, do thought experiments,...)	students can only decide which parents to cross	for own presentation, or to challenge others
DO EXPERIMENT, make OBSERVATIONS	GCK provides data, students observe & use it	planned by presenters, or due to challenge
theories + system → PREDICTION (using "if-then" deductive logic)	for old or new Ts, to explain or predict	prediction must be done BEFORE an experiment
estimate degree-of-AGREEMENT, by comparing obs with T-predictions	this is usually the major factor in T-evaluation	this is most important factor in persuasion
estimate degree-of-CONTRAST, compare obs-vs-predn for T & alt-Ts	students can recognize "crucial experiments"	if needed to compare competitive models
PREVIOUS agreement-and-contrast (empirical evaltn for previous expmts)	all data is considered	yes
INTERNAL characteristics of Theory (check T's ontology, systematicity,...)	yes	yes
EXTERNAL relations with other Ts (domain overlap, shared components)	yes	yes
metaphysical & ideological	consistency expected, if sophistication & patience	consistency
psychological, practical, authority	social interactions; also practical + authority	w students inside and outside group, and Sue
EVALUATION → "conclusion" Δ in T-status? retain revise reject delay	reject old model(s), maybe accept new model	reject the old model ? accept the new model ?
• **PERSUASION** (of self, research group, or outsiders)	yes, at several levels	external persuasion is now the main event

abbreviations: obs = observations, T = theory, predn = prediction, alt = alternative, evaltn = evaluation, expmts = experiments, Δ = change; w = with

Table 7: Science Experiences during the "Manuscript Preparation" activities

	3.35$_A$ Manuscript Writing and Manuscript Revising
• **PREPARATION** for content, process; backward-reaching, forward-reaching	backward-reaching: all preceding course activities forward-reaching: skill transfer to school and life
• **POSING** of an *area* to study, and of *constraints* on a	yes, there is freedom to make area-posing decisions
• **PROBING** pursuit: invent, evaluate, and execute probing-actions	can pursue a solution for a genetics problem or for a "writing the paper" problem
SELECT an old theory (observations + retroductive logic +...)	no; each group writes about an old model it selects,
INVENT a new theory (observations + retroductive logic +...)	if desired, the invented model can be revised
DESIGN EXPERIMENT (find gaps, do thought experiments,...)	goal can shift from *heuristic* experiments to *demonstration* experiments
DO EXPERIMENT, make OBSERVATIONS	if necessary to gather data for the paper, can do new demonstration experiments
theories + system → PREDICTION (using "if-then" deductive logic)	predictions are made after observations are known,
estimate degree-of-AGREEMENT, by comparing obs with T-predictions	this is the most important factor in students' strategies for effective scientific persuasion
estimate degree-of-CONTRAST, compare obs-vs-predn for T & alt-Ts	to contrast a new model's correct predictions with the incorrect predictions of an old model
PREVIOUS agreement-and-contrast (empirical evaltn for previous expmts)	demonstration experiments are selected from the pool of all previous experiments
INTERNAL characteristics of Theory (check T's ontology, systematicity,...)	formulate a smooth internal/external blending of all T-components: inheritance patterns, meiosis,...
EXTERNAL relations with other Ts (domain overlap, shared components)	
metaphysical & ideological	assumption of consistency
psychological, practical, authority	to persuade effectively, ask "What are the most influential personal motivations for my readers?"
EVALUATION → "conclusion" Δ in T-status? retain revise reject	the goal is to seek acceptance (high status) for the group's newly invented model
• **PERSUASION** (of self, research group, or outsiders)	external persuasion is the main goal of this activity

abbreviations: obs = observations, T = theory, predn = prediction, alt = alternative, evaltn = evaluation, expmts = experiments, Δ = change

Table 8: Functional Relationships between and within Instructional Activities

note: This table, with the page in "landscape" orientation
so you can see the entire table, is in another PDF-file.

	3.31$_{AC}$ Black Box **model**	3.31$_{B}$ Black Box con-	3.32$_{AB}$ *cookies variations pedigrees*	3.33$_{A}$ construct ***Mendel model***	3.33$_{B}$ construct ***meioticm odel***	3.33$_{C}$ GCK with no revising	3.34$_{A}$ GCK **model revising**	3.34$_{B}$ GCK con- ference	3.35 manu- script
backward preparation	none	**model revising**					**all** prior activities	**model revising**	**model revising**
forward preparation	**process**		*content*	**content process**	**content process**	content GCK	for per- suasion		
Posing	no, yes						**no**, yes		yes, yes
Probing for PSolving	**YES !**	**prsuasn**		**guided**	**guided**		**YES !**	**prsuasn**	**prsuasn**
Model Selection	old M				mitosis		**old Ms**		
Model Invention	**MODEL**			**model**	**model**	—	**MODEL**	for	
Expmtal Design	physical	for					limited	for	for
Expmt & Obs	expmt		obs	obs	remember	mental	MENTAL		
Prediction	**w new**	pre-dict					**w new**	pre-dict	
Agreement	main criterion	main argument		main criterion	main criterion	agreement	main criterion	main argument	main argument
Predictive Contrast						no alt-Ms			
Previous Expmts									
Internal Consistency									
External Consistency	with laws						w old Ms		
Metaphysical						**cnsstcy**			
Personal / Authority			bonding						
Conclusion	by group	by others		as class	as class		by group	by others	by others
Persuasion	**in** group	**external**		**by tchr**	**by tchr**		**in** group	**external**	**external**

abbreviations: prsuasn = persuasion, M = model, MB = Mendel's Bible, expmt = experiment, obs = observation, alt = alternative,
cnsstcy = consistency, motivn = motivation, tchr = teacher

Figure 15: an external representation for a model of simple **dominance**.

OView 0-A: theory for dominance

Punnet Squares (for genotypes) and phenotypes

	aa A	**ab** A	**bb** B
aa A	aa aa aa aa A A A A	aa ab aa ab A A A A	ab ab ab ab A A A A
ab A	aa aa ba ba A A A A	aa ab ba bb A A A B	ab ab bb bb A A B B
bb B	ba ba ba ba A A A A	ba bb ba bb A B A B	bb bb bb bb B B B B

OView 0-B: statistics for phenotypes

	aa A	**ab** A	**bb** B
aa A	100% A	100% A	100% A
ab A	100% A	75% A 25% B	50% A 50% B
bb B	100% A	50% A 50% B	100% B

OView 0-C: the 6 "cross possibilities"

	aa A	**ab** A	**bb** B
aa A	100% A	100% A	100% A
ab A	**same as aa x ab**	75% A 25% B	50% A 50% B
bb B	**same as aa x bb**	**same as ab x bb**	100% B

OView 0-D: theory-predicted data for dominance

	father A	father B
mother A	100% A or 75% A 25% B	100% A or 50% A 50% B
mother B	100% A or 50% A 50% B	100% B

Figure 16: Data and Theory for **codominance** in Round 1

OView 1-A: data and anomalies

	C	D	E
C	100% C	50% C 50% D	**100% D**
D	50% C 50% D	**25% C** **50% D** **25% E**	50% D 50% E
E	**100% D**	50% D 50% E	100% E

In addition, there are "missing results";

DxD never produces 100% D, and

no 'like with like' cross (CxC, DxD, ExE) ever produces a 75-25 mix.

OView 1-B: theory for codominance

	cc C	**ce** D	**ee** E
cc C	cc cc cc cc C C C C	cc ce cc ce C D C D	ce ce ce ce D D D D
ce D	cc cc ec ec C C D D	cc ce ec ee C D D E	ce ce ee ee D D E E
ee E	ec ec ec ec D D D D	ec ee ec ee D E D E	ee ee ee ee E E E E

OView 1-C: statistics for phenotypes

	cc C	**ce** D	**ee** E
cc C	100% C	50% C 50% D	100% D
ce D	50% C 50% D	25% C 50% D 25% E	50% D 50% E
ee E	100% D	50% D 50% E	100% E

Figure 17: Data and Theory for **multiple alleles** in Round 2

OView 2-A: data for dominance

	A	B
A	100% A or 75% A 25% B	100% A or 50% A 50% B
B	100% A or 50% A 50% B	100% B

OView 2-B: data for codominance

	cc C	**ce** D	**ee** E
cc C	100% C	50% C 50% D	100% D
ce D	50% C 50% D	25% C 50% D 25% E	50% D 50% E
ee E	100% D	50% D 50% E	100% E

OView 2-C: data for multiple alleles, and clues for anomaly resolution

	R	O	S	T
R	100% R or 75% R 25% T	50% R 50% O or 50% R 25% O 25% S	100% O or 50% R 50% O or 50% O 50% S or 25% R 25% O 25% S 25% T	100% R or 50% R 50% T
O		25% R 50% O 25% S	25% R 25% O 50% S or 50% O 50% S	50% R 50% S
S			100% S or 75% S 25% T	100% S or 50% S 50% T
T				100% T

Figure 17 (continued)

OView 2-D: theory for multiple alleles

	rr R	rt R	rs O	ss S	st S	tt T
rr R	rr rr rr rr	rr rt rr rt	rr rs rr rs	rs rs rs rs	rs rt rs rt	rt rt rt rt
rt R		rr rt tr tt	rr rs tr ts	rs rs ts ts	rs rt ts tt	rt rt tt tt
rs O			rr rs sr ss	rs rs ss ss	rs rt ss st	rt rt st st
ss S				ss ss ss ss	ss st ss st	st st st st
st S					ss st ts tt	st st tt tt
tt T						tt tt tt tt

OView 2-E: phenotypes for one codominance, "t loses"

	rr R	rt R	rs O	ss S	st S	tt T
rr R	R R R R	R R R R	R O R O	O O O O	O R O R	R R R R
rt R		R R R T	R O R S	O O S S	O R S T	R R T T
rs O			R O O S	O O S S	O R S S	R R S S
ss S				S S S S	S S S S	S S S S
st S					S S S T	S S T T
T T						T T T T

OView 2-F: the 7 types of inhritance sub-patterns for 3 alleles

	3 varns dominance hierarchical	3 varns dominance r-p-s	4 varns codominance t wins	4 varns codominance t loses	4 varns codominance t splits	5 varns codominance for 2 of 3	6 varns codominance for 3 of 3
rr	R	R	R	**R**	R	R	R
ss	S	S	S	**S**	S	S	S
tt	T	T	T	**T**	T	T	T
rs	R	R	RS	**RS**	RS	RS	RS
st	S	S	T	**S**	S	ST	ST
rt	R	T	T	**R**	T	R	RT

Figure 18: Data and Theory for **sex linkage** in Round 3

OView 3-A: ratios for all offspring, anomalies w.r.t. dominance

	H	Z
H	100% H or 75% H 25% Z	100% H or 50% H 50% Z
Z	50% H 50% Z but not 100% H	100% Z

OView 3-B: ratios for females & males; anomalies w.r.t. dominance

	H	Z
H	100% Hf 100% Hm or 100% Hf 0% Zf 50% Hm 50% Zm	100% Hf 100% Hm or 50% Hf 50% Zf 50% Hm 50% Zm
Z	100% Hf 100% Zm	100% Zf 100% Zm

OView 3-C: theory for dominance

	hh H	**hz** H	**zz** Z
hh H	hh hh hh hh H H H H	hh hz hh hz H H H H	hz hz hz hz H H H H
hz H	hh hh zh zh H H H H	hh hz zh zz H H H Z	hz hz zz zz H H Z Z
zz Z	zh zh zh zh H H H H	zh zz zh zz H Z H Z	zz zz zz zz Z Z Z Z

OView 3-D: theory for sex-linkage

	h– H	**z–** Z
hh H	hh h– hh h– Hf Hm Hf Hm	hz h– hz h– Hf Hm Hf Hm
hz H	hh h– zh z– Hf Hm Hf Zm	hz h– zz z– Hf Hm Zf Zm
zz Z	zh z– zh z– Hf Zm Hf Zm	zz z– zz z– Zf Zm Zf Zm

Figure 19: Data and Theory for **autosomal linkage** in Round 4

OView 4-A: Punnett Squares for the same phenotype-cross (AI x AI), using two different genotype-crosses: "aaii x aaii" on the left side, "abin x abin" on the right side.

AI (aa ii)	AI (aa ii) ai
a i	aa ii A I

ratio (AI:AN:BI:BN) is 1:0:0:0

AI (ab in)	AI (ab in) ai	AI (ab in) an	AI (ab in) bi	AI (ab in) bn
ai	aa ii AI	aa in AI	ab ii AI	ab in AI
an	aa ni AI	aa nn AN	ab ni AI	ab nn AN
bi	ba ii AI	ba in AI	bb ii BI	bb in BI
bn	ba ni AI	ba nn AN	bb ni BI	bb nn BN

ratio (AI:AN:BI:BN) is 9:3:3:1

OView 4-B: Phenotype data, predicted using Punnett Squares, for all genotype combinations.
Data shows ratios for AI:AN:BI:BN. For example, for AIxAI one of the 16 cells is "6200" to show the 6:2:0:0 ratio, with 75% AI, 25% AN, 0% BI, and 0% BN.
The shaded cells are predictions that, with linkage, do not match observations.

		AI aa ii	AI aa in	AI ab ii	AI ab in	AN aa nn	AN ab nn	BI bb ii	BI bb in	BN bb nn
AI	aa ii	8000	8000	8000	8000	8000	8000	8000	8000	8000
AI	aa in	8000	6200	8000	6200	4400	4400	8000	6200	4400
AI	ab ii	8000	8000	6020	6020	8000	6020	4040	4040	4040
AI	ab in	8000	6200	6020	**9331**	4400	**3311**	4040	**3131**	**2222**
AN	aa nn	8000	4400	8000	4400	0800	0800	8000	4400	0800
AN	ab nn	8000	4400	6020	**3311**	0800	0602	4040	2222	0404
BI	bb ii	8000	8000	4040	4040	8000	4040	0080	0080	0080
BI	bb in	8000	6200	4040	**3131**	4400	2222	0080	0062	0044
BN	bb nn	8000	4400	4040	**2222**	0800	0404	0080	0044	0008

OView 4-C: Punnett Squares, if there is autosomal linkage, for the four anomalous crosses. The bold numbers show the phenotype ratios for each area; non-bold numbers show the ratios that occur if there is no linkage, when all cells are combined.

		AI		AI	
		ai	bn	an	bi
AI	ai	aa ii AI	ab in AI	aa in AI	ab ii AI
	bn	ba ni AI	bb nn BN	ba nn AN	bb ni BI
AI	an	aa ni AI	ab nn AN	aa nn AN	ab ni AI
	bi	ba ii AI	bb in BI	ba in AI	bb ii BI

6002 **4220**

4220 **4220**

9331 if combined

		AI		AI	
		ai	bn	an	bi
AN	an	aa ni AI	ab nn AN	aa nn AN	ab ni AI
	bn	ba ni AI	bb nn BN	ba nn AN	bb ni BI

4202 **2420**

3311 if combined

		AI		AI	
		ai	bn	an	bi
BI	bi	ba ii AI	bb in BI	ba in AI	bb ii BI
	bn	ba ni AI	bb nn BI	ba nn AI	bb ni BI

4022 **2240**

3131 if combined

		AI		AI	
		ai	bn	an	bi
BN	bn	ba ni AI	bb nn BN	ba nn AN	bb ni BI
	bn	ba ni AI	bb nn BN	ba nn AN	bb ni BI

4004 **0440**

2222 if combined

OView 4-D: Dominance with autosomal linkage; an explanation for anomalies in OView 4D.
The shading shows parental genotypes that produce different gametes if there is linkage, and the cross-results that (as shown in OView 4-D) are anomalous.

	AI aa ii	AI aa in	AI ab ii	AI ab in	AI ab in	AN aa nn	AN ab nn	BI bb ii	BI bb in	BN bb nn
	ai ai	ai an	ai bi	ai bn	an bi	an an	an bn	bi bi	bi bn	bn bn
ai ai	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000
ai an	8000	6200	8000	6200	6200	4400	4400	8000	6200	4400
ai bi	8000	8000	6020	6020	6020	8000	6020	4040	4040	4040
ai bn	8000	6200	6020	**6002**	**4220**	4400	**4202**	4040	**4022**	**4004**
an bi	8000	6200	6020	**4220**	**4220**	4400	**2420**	4040	**2240**	**0440**
an an	8000	4400	8000	4400	4400	0800	0800	8000	4400	0800
an bn	8000	4400	6020	**4202**	**2420**	0800	0602	4040	2222	0404
bi bi	8000	8000	4040	4040	4040	8000	4040	0080	0080	0080
bi bn	8000	6200	4040	**4022**	**2240**	4400	2222	0080	0062	0044
bn bn	8000	4400	4040	**4004**	**0440**	0800	0404	0080	0044	0008

OView 4-E: This shows why the results with no linkage (on the left, as in OView 4-A) are the same as the overall results with linkage (on the right, as in OView 4-C). 4 of 16 results (in 4-A) can occur with the "#1" set of linked parents (in 4-C); the other 12 results (in 4-A) occur with the other three parental crosses in 4-C.

(ab in)

a b i n	ai	an	bi	bn
ai	aa ii #1	aa in 2	ab ii 2	ab in #1
an	aa ni 3	aa nn 4	ab ni 4	ab nn 3
bi	ba ii 3	ba in 4	bb ii 4	bb in 3
bn	ba ni #1	ba nn 2	bb ni 2	bb nn #1

(ab in)

a b i n	ai	bn	an	bi
ai	aa ii #1	ab in #1	aa in 2	ab ii 2
bn	ba ni #1	bb nn #1	ba nn 2	bb ni 2
an	aa ni 3	ab nn 3	aa nn 4	ab ni 4
bi	ba ii 3	bb in 3	ba in 4	bb ii 4

OView 4-F: Comparing predictions (from 4-A or 4-B) with observations (from 4-C or 4-D). 1
Bold print shows anomalies: ratios that (at left) are predicted but not observed
or ratios that (at right) are observed but not predicted. 7

predictions

	AI	AN	BI	BN
AI	8000 6200 6020 **9331**	8000 4400 6020 **3311**	8000 6200 4040 **3131**	8000 4400 4040 **2222**
AN	8000 4400 6020 **3311**	0800 0602	8000 4400 4040 2222	0800 0404
BI	8000 6200 4040 **3131**	8000 4400 4040 2222	0080 0062	0080 0044
BN	8000 4400 4040 **2222**	0800 0404	0080 0044	0008

observations

	AI	AN	BI	BN
AI	8000 6200 6020 **4220** **6002**	8000 4400 6020 **4202** **2420**	8000 6200 4040 **4022** **2240**	8000 4400 4040 **4004** **0440**
AN	8000 4400 6020 **4202** **2420**	0800 0602	8000 4400 4040 2222	0800 0404
BI	8000 6200 4040 **4022** **2240**	8000 4400 4040 2222	0080 0062	0080 0044
BN	8000 4400 4040 **4004** **0440**	0800 0404	0080 0044	0008

OView 4-G: Predicted results for phenotype crosses, based on the data in OView 0-A.
The numbers shows the predicted percentages of B and N for each trait-cross. For example, for AxA there is a "25 or 0" to show that the predicted result is "either 25% B (and therefore 75% A) or 0% A (and 100% B)."

	AI	AN	BI	BN
AI	AxA: 25 or 0 IxI: 25 or 0	AxA: 25 or 0 IxN: 50 or 0	AxB: 50 or 0 IxI: 25 or 0	AxB: 50 or 0 IxN: 50 or 0
AN	AxA: 25 or 0 NxI: 50 or 0	AxA: 25 or 0 NxN: 100	AxB: 50 or 0 NxI: 50 or 0	AxB: 50 or 0 NxN: 100
BI	BxA: 50 or 0 IxI: 25 or 0	BxA: 50 or 0 IxN: 50 or 0	BxB: 100 IxI: 25 or 0	BxB: 100 IxN: 50 or 0
BN	BxA: 50 or 0 NxI: 50 or 0	BxA: 50 or 0 NxN: 100	BxB: 100 NxI: 50 or 0	BxB: 100 NxN: 100

OView 4-H: Predicted phenotype data for all phenotype-combinations shown in OView 4-A.

	AI			AN			BI			BN		
	%B	%N	data	%B	%N	data	%B	%N	data	%B	%N	data
	25	25	8000	25	50	8000	50	25	8000	50	50	8000
AI	25	0	6200	25	0	4400	50	0	6200	50	0	4400
	0	25	6020	0	50	6020	0	25	4040	0	50	4040
	0	0	9331	0	0	3311	0	0	3131	0	0	2222
	25	50	8000	25	100	0800	50	50	8000	50	100	0800
AN	25	0	4400	0	100	0602	50	0	4400	0	100	0404
	0	50	6020				0	50	4040			
	0	0	3311				0	0	2222			
	50	25	8000	50	50	8000	100	25	0080	100	50	0080
BI	50	0	6200	50	0	4400	100	0	0062	100	0	0044
	0	25	4040	0	50	4040						
	0	0	3131	0	0	2222						
	50	50	8000	50	100	0800	100	50	0080	100	100	0008
BN	50	0	4400	0	100	0404	100	0	0044			
	0	50	4040									
	0	0	2222									

Figure 20: A Super-Punnett Overview for a "3 alleles per individual" theory.

		aaa		**aad**		**add**	**ddd**
		a	**a**	**d**	**a**	**d**	**d**
aaa	**aa**	aaa A	aaa A	aad B	aaa A	aad B	aad B
aad	**aa**	aaa A	aaa A	aad B	aaa A	aad B	aad B
	ad	ada B	ada B	add C	ada B	add C	add C
add	**ad**	ada B	ada B	add C	ada B	add C	add C
	dd	dda C	dda C	ddd D	dda C	ddd D	ddd D
ddd	**dd**	dda C	dda C	ddd D	dda C	ddd D	ddd D

Figure 21: A Summary of Research on GCK-based Problem Solving

	date of study	date of dissrtn	GCK used?	at MG?	interpretive framework	individuals or groups?	skill level	focus of research
Collins	—	1986	yes	no	Reif (PS)	individuals	novice	strategies
Thomson	—	1993	yes	no	Darden	individuals	expert	strategies
Hafner	1990	1991	yes	yes	MRPSG	individuals	novice	strategies
Finkel	1992	1993	yes	yes	Sociology of Science	groups	novice	interactions & strategies
Wynne	1993	1995	yes	yes	Clement,...	groups	novice	strategies
Lem-berger	1994	1995	yes	yes	Conceptual Change	groups	novice	concepts & instruction
Johnson	1992	1996	yes	yes	Darden	groups	novice	strategies
Rusbult	1992-94	1997	yes	yes	ISM	groups	novice	instruction

Figure 22: The relative complexity of models proposed by students.

my name for the model	alleles in population	alleles in individual	number of phenotypes	number of genotypes	total number of crosses	non-duplicate crosses
2-and-2	2	2	2 or 3	3	9	6
3-and-2	3	2	3 to 6	6	36	21
4-and-2	4	2	4 to 10	10	100	55
2-and-3	2	3	2 to 4	4	72	36
3-and-3	3	3	3 to 10	10	648	324
4-and-3	4	3	4 to 20	20	3200	1600
4-and-4	4	4	4 to 35	35	2450	1225

The "total number of non-duplicate crosses" refers to either crosses where genotypes vary (for models with 2 alleles per individual) or to crosses where the genotypes and/or phenotypes vary (for models with 3 or 4 alleles per individual), as explained in Section B15.

Section B15 contains a Prediction Overview, with accompanying explanation, for an easy way to represent the 36 crosses in the '2-and-3' model. A similar system can be used for the other models that have 3 or 4 alleles per individual, although it is questionable whether there can be an "easy" way to do the 324 crosses (or more!) that are possible for these models.