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AN INTERDISCIPLINARY AND SYSTEMS-BASED EVALUATION OF ACADEMIC PROGRAMS: BOVINE MASTITIS-RELATED VETERINARY RESEARCH, EDUCATION AND OUTREACH

A. L. RIVAS,[1*] D. J. WILSON,[1] R. N. GONZALEZ,[1] H.O. MOHAMMED,[2] F. W. QUIMBY,[3] D. H. LEIN,[4] R. A. MILLIGAN,[5] R. D. COLLE,[6] J. D. DESHLER,[7] W. M. K. TROCHIM[8]

[1]Quality Milk Promotion Services, [2]Department of Clinical Sciences. [3] Department of Pathology, [4]Diagnostic Laboratory, College of Veterinary Medicine, [5]Department of Agricultural, Resource and Managerial Economics, [6]Department of Communications, [7]Department of Education, College of Agriculture and Life Sciences,[8] Department of Human Services, College of Human Ecology, Cornell University, Ithaca, NY 14853 (USA)

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An interdisciplinary and systems-oriented approach for evaluation of academic programs was explored in veterinary research, education and extension in the context of prevention of bovine mastitis. Bibliometric-based document analysis and observation methods were used to assess disciplinary contents of veterinary research and graduate education theses, and New York State dairy farmers' adoption rate of selected veterinary recommendations (bacteriological testing of raw milk, "closed herds", and three hygiene-related practices). Findings indicated that: a) the veterinary extension literature was lower in output and less differentiated in disciplinary content than that of the agricultural counterpart; b) three disciplines accounted for 58% of all theses' major contents; and c) 39.7% of New York dairies requested bacteriological testing, 50% of investigated dairies had "closed herds" and at least 9.4% of those did not adopt all the hygiene-related practices. Context-specific recommendations are proposed. It is concluded that this evaluation approach may facilitate policy analysis, program development and may be applicable to other academic settings.

Introduction

The rapid obsolescence of scientific information – among other reasons – makes answering the question of whether academic programs are adequate for individuals and society particularly challenging today. Formative evaluations have been defined as those aimed at providing information about programs so that they can be improved.[1] Formative evaluations are meant to be action-oriented.[2] However, since evaluation

*Corresponding author: xx-607-255-8202 (telephone), xx-607-257-8485 (fax), alr4@cornell.edu (e-mail).

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methods always need to be contextualized, successful interdisciplinary interactions among evaluators and specialists/subject matter experts may be a major limiting factor of the evaluative enterprise. These considerations lead us to postulate that the success of academic evaluations may depend on the interdisciplinary breadth and functional complementarity of their components.

We have suggested before that interdisciplinary interactions may depend on the availability of professionals with training and professional experience in two or more professions so that they can facilitate communications across disciplines. These multiprofession/multipractice individuals are needed to translate concepts originated in the field into terms operational within individual specialties (*converging* communications) and, conversely, to translate concepts originated within an individual specialty into languages operational within other specialties and the public at large (*diverging* communications).[3]

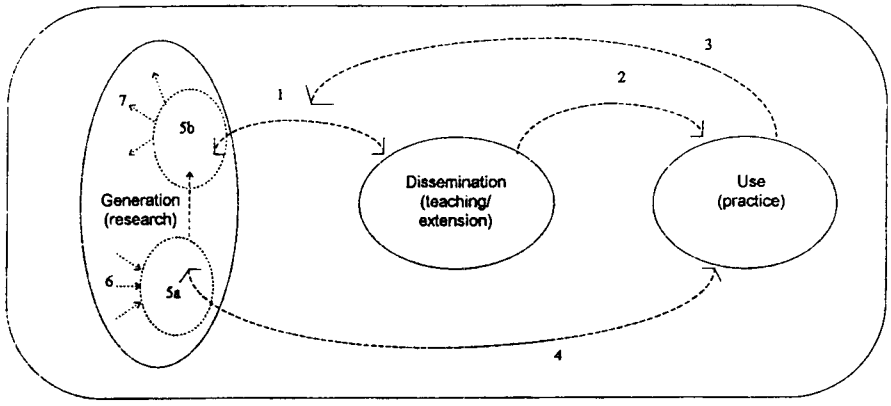

Fig. 1. A Systems-based view of academic knowledge systems. The veterinary academic knowledge system is conceptualized as composed of knowledge (or information) generation (i.e., academic research), dissemination (i.e., conventional teaching and extension), and use subsystems (i.e., professional practice). Feedforward and feedback connections (#1-4) provide data that could be used in policy analysis, program evaluation and program development. An additional, fourth subsystem (information integration) is proposed which would be composed of *converging* communications (#6) where hypothesis generation is promoted (#5a), and hypothesis testing and *diverging* communications (#5b and 7).

Formative evaluation may be facilitated by Systems theory. Following *Havelock*, we have proposed that a *knowledge system* can be defined as a set of linkages connecting knowledge generation (i.e., academic research), knowledge dissemination (i.e., conventional teaching and extension), and knowledge use (i.e., professional practice).[4–6]

In the area of veterinary medicine (and within the context of dairy agriculture) these subsystems may be viewed as indicated in Fig. 1. The *veterinary knowledge system* may thrive and be sustained if these linkages (feedback and feedforward) are adequately connected (e.g., if each sub-system is able to communicate with any of the other sub-systems). Disconnections between these subsystems could result in inadequate knowledge use. For instance, when research (knowledge generation) is abundant, but there is only a one-way communication linkage that connects the knowledge generation with the use sub-system (with no feedback between practice and research) knowledge users (i.e., farmers) might be prevented from using knowledge potentially available. This event could occur when there are problems at the level of veterinary training, information delivery, farmers' cognitive basis on biological issues, or impediments for practitioner-farmer communications. In addition, lack of feedback between knowledge users and the knowledge generation and dissemination subsystems might prevent from developing *adaptive* and other type of research needed by practitioners and farmers. Thus, evaluation of veterinary programs following a Systems view may facilitate the identification of all system components and provide information about individual knowledge sub-systems and the knowledge system as a whole.

Infectious bovine mastitis provides a context within which this Systems approach can be investigated. Bovine mastitis is a disease of major importance for dairy agriculture. Although significant research and extension efforts have been implemented in the last three decades, its prevalence has not decreased significantly – or has increased.[7,8] For example, approximately two billion dollars are lost every year in the US due to bovine mastitis.[9] Investigating the bovine mastitis-related veterinary knowledge system might generate theories on factors with explanatory potential about why the prevalence of bovine mastitis has not decreased. This veterinary knowledge system may be examined through assessments of: a) the extent and disciplinary contents of scientific research related to *prevention of bovine mastitis* (PBM); b) the extent and disciplinary contents of PBM-related veterinary graduate education; and c) farmers' adoption of veterinary practices recommended for PBM (Fig. 1A, B and C).

Bibliometric-based research methods may facilitate the evaluation of two of these three postulated veterinary knowledge subsystems.[10] By searching publications that contain the same keywords in their abstract or title, computer software with Boolean

algorithms (currently available in most large databases such as *CAB Abstracts* and *Agricola*), may sort publications that share one or more concepts and evaluate the knowledge generation sub-system. We and others have used bibliometrics to investigate research growth and disciplinary differentiation trends in biomedical professions.[3,11] Evaluation of graduate education may be implemented with a similar bibliometric-based research method. Analysis of veterinary theses' contents (as reflected in their abstracts which is reported by the database *Dissertation Abstracts International*) may indicate the disciplinary contents and connections across disciplines that characterize a field such as PBM.

Assessment of veterinary recommendations actually used in the field should reflect the level of knowledge use. Among several practices used to prevent bovine mastitis, three hygiene-related recommendations have been promoted for 12 to 30 years: 1) postmilking teat disinfection,[12] 2) nonlactating cow therapy,[13] and 3) premilking teat disinfection.[14,15] More recently, bacteriological testing of raw milk has been reported to be the gold standard for measuring intramammary infections.[16,17] We and others have promoted "closed herds" (complemented with bacteriological testing and quarantining when new animals are introduced).[18] The adoption rate of some veterinary practices recommended for prevention of bovine mastitis has been examined before.[19–24] The adoption rate of milk bacteriological testing has been reported just once.[25] The adoption rate of these five practices has not been investigated in New York State.

This study examined a formative evaluation approach that included both a Systems and an interdisciplinary perspective. This study was contextualized within academic veterinary programs oriented for prevention of infectious bovine mastitis.

Materials and methods

This study utilized document analysis and observation. Bibliometric-based document analysis was used to identify the disciplinary content and output of: 1) research publications as reported by two major databases on agricultural scientific literature, and 2) veterinary graduate theses as reported in their abstracts. Observation (and document analysis) were used to assess farmers' adoption of veterinary recommended practices.

Assessment of the veterinary extension-related research literature

The veterinary extension-related literature in general, and the bovine mastitis-related literature in particular, were analyzed from two databases: *CAB Abstracts* and *Agricola*. *CAB Abstracts* (source: CAB International) indexes agriculture-related information (crop and animal sciences) and covers about 10,000 serials since 1972. *Agricola* (source: US National Agriculture Library) is a database of citations and abstracts indexed from approximately 5,000 journals since 1982. The non-veterinary agricultural literature was examined for comparative purposes.

Assessment of graduate theses' disciplinary contents

All theses' abstracts reported by *Dissertation Abstracts International* between January 1993–March 1997 which included the keywords *bovine mastitis* and *intramammary infections* were sorted (n=43). In order to control for descriptor inaccuracy, abstracts were analyzed by a team of 5 veterinarians with expertise in multiple disciplines who followed a Delphi-based procedure.[26] In brief, abstracts were read and identified by each expert, results communicated to a panel facilitator who removed those theses on which a consensus had been reached, and returned the remaining abstracts for a new round of analysis until a consensus about each thesis' disciplinary contents was reached for all theses.

Adoption of veterinary recommendations for prevention of bovine mastitis

The adoption rate of five veterinary recommendations (bacteriological testing of bovine milk, closed herds, postmilking teat disinfection, nonlactating cow therapy, and premilking teat disinfection), were investigated. Adoption of "closed herds"* and hygiene-related practices were assessed through observations conducted on 1507 visits to New York State dairy farms conducted between 1994 and 1995. Observers were QMPS** technicians and veterinarians. They recorded management practices and farm characteristics. At each farm visit, observations on milking system, milking methods,

* Closed herds is a practice consisting of isolation of dairy herds (with no introduction of new animals to the herd) or, alternatively, with introduction of purchased animals only after quarantine and bacteriological testing indicate that the new animals do not carry diseases (i.e., *Streptococcus agalactiae*).

** The Quality Milk Promotion Services (QMPS) is a dairy farming service-oriented program associated with the College of Veterinary Medicine of Cornell University, Ithaca, NY, USA.

lactation and dry cow therapy, environmental sanitation (including housing, bedding, barn and pasture management), milk production and milk somatic cell count (SCC) were recorded in a four-page questionnaire (not shown). Adoption of bacteriological testing was assessed through document analysis (records on users of QMPS between 1994 and 1995). Computer software was developed for this purpose at QMPS (LabMan©) in order to standardize records of all QMPS clients. Data on the total number of dairy farms in New York State (denominator of the bacteriological adoption rate) was obtained from the US Department of Agriculture (National Agricultural Statistics Service, report 3050, January 31, 1997).

Statistical analysis

Proportions of adoption vs. non-adoption rates, and bibliographic references in veterinary medicine vs. agriculture were analyzed by the χ^2 test. Analyses were performed with the *Minitab* statistical software.[27]

Results

Assessment of the veterinary bovine mastitis-related research literature

CAB Abstracts database. A search of this database reported 227,183 publications under *agriculture* and 199,161 publications under *veterinary* between 1972-1996 (Table 1). Agricultural publications were 1.14 times more numerous than veterinary publications (Table 2). In order to control for size of the research community (larger in agriculture), *extension* publications were reported as a percent of each profession's total literature. Agricultural (non-veterinary) extension references represented 3.11% of all agricultural publications (7,070/227,183), while veterinary (agricultural and non-agricultural) extension publications represented 0.37% of all veterinary publications (732/199,161). Expressed as a percentage of total publications within each profession, agricultural extension publications outweighted veterinary extension publications 8.4 times ($P < 0.01$, χ^2 test, Table 1).

Table 1
Research in agricultural and veterinary extension

	CAB Abstracts	*Agricola*
A. Output.		
Agriculture (agr):	227,183	121,679
Veterinary (vet m):	199,161	48,603
Extension (ext):	30,445	53,070
Ext and *agr*:	7,070	8,050
Ext and *vet m*:	732	208
Dairy extension (dairy ext):	1,214	1,745
Dairy ext and *agr*:	250	304
Dairy ext and *vet m*:	108	19
B. Disciplinary contents.		
Extension economics (ext econ):	3,244	3,173
Ext econ and *agr*:	1,273	1,378
Ext econ and *vet m*:	65	7
Extension education (ext educ):	3,489	2,842
Ext educ and *agr*:	1,166	750
Ext educ and *vet m*:	91	10
Extension evaluation:	1,923	1,304
Extension eval and *agr*:	486	253
Extension eval and *vet m*:	48	7
Extension communications (ext comm):	327	849
Ext comm and *agr*:	114	75
Ext comm and *vet m*:	9	4
Extension sociology:	497	154
Ext soc and *agr*:	172	57
Ext soc and *vet m*:	9	0
Innovation adoption (inn adop):	2,702	936
Inn adop and *agr*:	773	170
Inn adop and *vet med*:	24	2

Sources: *CAB Abstracts* (1972-December 1996) and *Agricola* (1982-December 1996) databases. Searched keywords are italicized.

Social science contents were highly represented in *extension*. They included economics, education, evaluation, communication, and sociology. These five fields represented as much as 31.1% of all extension publications: extension economics represented 10.6% (3,244/30,445); extension education represented 11.5% 3,489/30,445); extension evaluation represented 6.3%; extension communications represented 1.1% (327/30,445); and extension sociology represented 1.6% (497/30,445). Social contents of extension were represented more in agricultural extension publications than in veterinary extension publications (45.4% vs 30.2%, respectively, Table 1).* Analysis of adoption of innovations, an interdisciplinary field closely related to extension, indicated 524 agricultural references and 12 veterinary references. Publications on bovine mastitis extension were negligible both in agriculture and in veterinary medicine (Table 2). Research on adoption of professional recommendations to prevent bovine mastitis was also limited.

Agricola database. References sorted by *Agricola* showed results similar in trend to those of *CAB Abstracts* (Table 1). Additional profiles were suggested along geographical categories. Non-American countries accounted for 90% of all veterinary extension publications in 1992-1995 (Table 2).

Assessment of graduate theses' disciplinary contents

Table 3 shows the year of completion, country of origin and disciplinary content(s) of professional and graduate education programs that resulted in a thesis where the abstract was reported by *Dissertation Abstracts International*. Thirteen disciplines were reported as major disciplines (and three additional disciplines, not reported es majors, were reported as minor disciplines). Of these sixteen disciplines, three (immunology, epidemiology, and animal sciences) accounted individually for ≥11% (and collectively, for 58.1%) of all theses' major contents (Fig. 2). Interestingly, microbiology was not among those, but it was the most frequent minor discipline. Molecular biology, reported three times as the minor discipline was only once reported as a major discipline. Disciplines such as economics, education, communication were not observed as major contents. Many theses appeared to have only a single disciplinary emphasis, only one thesis appeared to involve three disciplines and no thesis appeared to involve four or more disciplines. A time series analysis suggested that epidemiology has been the discipline most rapidly growing while immunology seems to be the one most frequently included in graduate theses (Fig.3).

* Cross-referencing among these five categories may result in a total number of publications less than the figure resulting from adding those five categories individually.

Table 2
Mastitis-related published research and relative development of the veterinary extension research literature

A. Mastitis.

Bovine mastitis (bov mast)	9,682
Adoption (adop)	8,080
Bacteriology (bact)	10,495
Agricultural extension (bovine mastitis)	4
Veterinary extension (bovine mastitis)	11
Bovine mastitis adoption	17
Bovine mastitis bacteriology adoption	0
Bovine mastitis culture adoption	1

B. Relative development of the veterinary extension research literature (compared to the agricultural counterpart).

Agriculture	227,183
Veterinary	199,161
Ratio Agric./Veter.	1.141
Agricultural extension	7,070
Veterinary extension	732
Ratio Agric./Veter.	9.658

Relative development of veterinary extension (in comparison to agriculture extension):

$$\text{Ratio} = \frac{\text{agricultural extension/veterinary extension}}{\text{agriculture/veterinary}} = \frac{9.658}{1.141} = 8.46$$

C. Veterinary extension publications in the Americas and the rest of the world.

Year	All countries	Americas	Year	All countries	Americas
1992	17	1 (Canada)	1994	16	1 (USA)
1993	10	1 (USA)	1995	16	3 (USA, Canada, Cuba)

Source: *CAB Abstracts* (1972-December 1996). Searched keywords are italicized.

Table 3
Bovine mastitis-related disciplinary contents of veterinary graduate education

Thesis abstract (#)	Country	Major discipline	Minor discipline(s)	Year
1	US[1]	Epidemiology		1996
2	Mexico	Nutrition		1996
3	Canada[2]	Immunology		1996
5	US[3]	Epidemiology		1995
6	Canada[2]	Nutrition	Immunology	1995
7	Canada[2]	Epidemiology	Immunology	1995
8	US[4]	Nutrition	Gynecology	1995
9	US[5]	Endocrinology		1995
10	Canada[6]	Cell biology	Immunology	1995
11	Canada[7]	Epidemiology	Extension, microbiology	1995
12	Sweden	Immunology	Virology	1995
13	Sweden	Animal Science	Nutrition	1994
14	Canada[6]	Cell biology		1994
15	US[8]	Immunology		1994
16	US[1]	Immunology	Microbiology	1994
18	US[9]	Immunology	Epidemiology	1993
19	US[10]	Endocrinology	Nutrition	1993
20	Canada[2]	Genetics		1993
21	US[1]	Molecular biology	Microbiology	1993
23	US[11]	Nutrition	Immunology	1993
24	Sweden	Cell biology		1993
26	US[12]	Epidemiology	Microbiology	1993
27	US[13]	Immunology	Molecular biology	1993
28	US[14]	Immunology		1993
29	US[15]	Epidemiology		1993
30	Austria	Animal Science	Microbiology	1993
32	Canada[7]	Epidemiology	Microbiology	1993
33	Norway	Immunology	Molecular biology	1993
34	US[16]	Epidemiology		1993
35	Canada[2]	Microbiology		1992
36	US[17]	Microbiology	Molecular biology	1992
37	US[1]	Immunology	Microbiology	1992
38	US[18]	Cell biology		1992
39	Canada[7]	Immunology		1992
42	Austria	Gynecology		1992
44	Ireland	Chemical engineering		1992
45	US[19]	Immunology		1992
47	Canada[20]	Epidemiology	Microbiology	1991
48	Denmark	Animal Science		1991
49	Austria	Animal Science		1991
50	Austria	Medicine		1990
1b	US[3]	Animal Science		1992
2b	Austria	Anatomy	Pathology	1992

Source: *Dissertation Abstracts International* (January 1993-March 1997). Universities: 1: Cornell; 2: Guelph; 3: Davis, California; 4: Michigan; 5: Mississippi; 6: McGill; 7: Prince Edward Island; 8: Ohio; 9: Iowa; 10: Minnesota; 11: Pennsylvania; 12: Washington State; 13: Maryland-Virginia; 14: Rutgers; 15: Kansas; 16: Arizona; 17: Utah; 18: Illinois; 19: Connecticut; 20: Alberta.

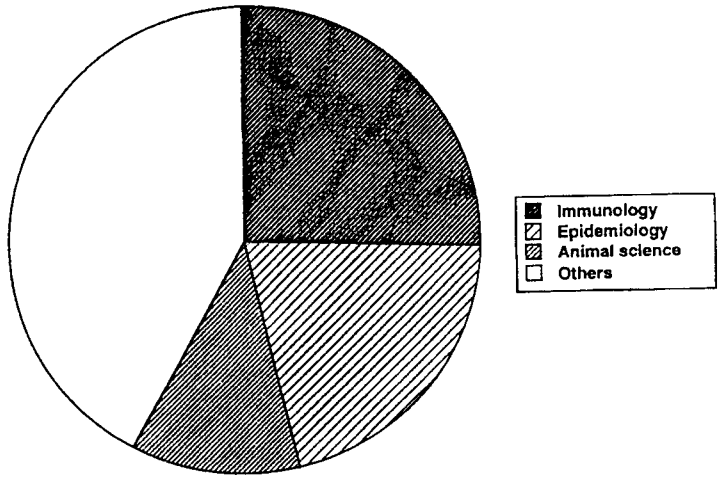

Fig. 2. Disciplinary contents of graduate education. I. Cumulative disciplinary contribution of bovine mastitis-related theses between 1992-1996. Source: *Dissertation Abstracts International*

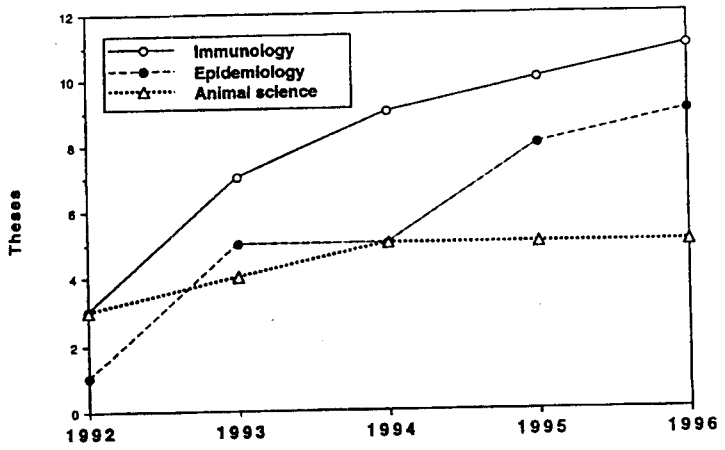

Fig. 3. Disciplinary contents of graduate education. II. Longitudinal disciplinary contribution of bovine mastitis-related theses between 1992-1996. Source: *Dissertation Abstracts International*

Adoption of veterinary recommendations for prevention of bovine mastitis

Adoption of bacteriological testing. Records on QMPS users indicated that 3,649 herds requested bacteriological testing from QMPS at least once in 1994-1995 (Table 4). They represented 39.7% of all New York State herds.

Table 4
Adoption of bacteriological testing of bovine raw milk in New York dairy herds

A. Total New York State dairy herds[a]	9,200
B. Total dairy herds served by QMPS (1994-1995)[b]	3,649
C. Dairy herds not served by QMPS	5,751
D. New York State mean herd size[b]	77 cows
E. Cow mastitis prevalence across herds due to	
1. *Strep. agalactiae*[c]	9.5%
2. *Staph. aureus*[c]	8.5%
3. *M. bovis*[c]	0.1%
F. Mean cost per mastitis case due to:	
1. *Strep. agalactiae*[c]	$ 179
2. *Staph. aureus*[c]	$ 160
3. *Mycoplasma bovis*[c]	$ 230
G. Hypothetical economic loss attributable to lack of etiologic diagnosis (herds that do not test milk bacteriologically), due to:	
1. *Strep. agalactiae* (C x D x E x F)	$ 7,531,000
2. *Staph. aureus* (C x D x E x F)	$ 6,022,000
3. *M. bovis* (C x D x E x F)	$ 102,000
	Total: $13,655,000

Sources: [a] Report 3050. NASS, US Department of Agriculture, Washington, DC. Jan. 31, 1997
[b] QMPS database.
[c] D.J. Wilson (unpublished data)

Adoption of hygiene-related practices. Although most dairies investigated appeared to adopt some preventive practices, none adopted ≥91% of all recommended practices. Most importantly, in spite of practices recommended for many years, different adoption rates were observed for complementary practices (Table 5).

Adoption of "closed herds." Closed herds, a practice that prevents the introduction of *Str. agalactiae* into healthy herds, was adopted by <50% of the investigated farms (Table 5).

Table 5
Adoption of "closed herds" and hygiene-related practices in New York dairy herds

Practices	Adoption rate
Closed herds	42.7% (643/1505)
Pre-dipping	54.4% (773/1420)
Post-dipping	82.5% (941/1140)
Both pre-dipping and post-dipping	51.8% (590/1140)
Teats clean	90.6% (1310/1446)
Udder preparation of any kind	70.5% (857/1215)
Dry cow therapy	89.1% (1343/1507)
all cows	78.4% (1182/1507)
"selected" cows	10.7% (161/1507)
"abrupt" Rx	77.0% (1034/1343)
"gradual" Rx	23.0% (309/1343)
No pre-dipping, post-dipping, or dry cow therapy	3.4% (39/1140)

Farms were visited between 3/2/94 and 11/30/95. Some variables (developed after 3/2/94) may result in the total number of responses being less than 1507. Mean milk production: 6,449 kg/cow. Questionnaires completed at farm visits: n=1507. Farms with production records: n=1251. Farms with production and somatic cell count (SCC) records: n=982. Farms with > 750,000 SCC/ml and 5,739 kg/cow: n=187. Farms with < 750,000 SCC/ml at visit (previously with > 750,000 SCC/ml twice in a 4-month period) and 5,863 kg/cow: n=364. Farms with < 750,000 SCC (voluntary bacteriological testing) and 7,252 kg/cow: n=431.

Source: Quality Milk Promotion Services (QMPS), Cornell University.

Discussion

Limitations

Discussion of the findings should consider the following limitations. Data reported may include both false positive and false negative information. For instance, bacteriological testing of raw milk could hypothetically be performed by laboratory services other than those provided by QMPS which would result in under-estimated adoption rates. This possibility, however, is unlikely since QMPS testing services are subsidized by New York State (and thus, more economical than any other alternative). Less than 2% of New York dairies are estimated to be serviced by other laboratories (González , personal communication). Another potential source of error might occur if relevant citation data has either been missed or their titles or abstracts did not contain the searched keywords (false negative results). Alternatively, references with contents not relevant but with wording including the searched keywords could have led to false positive results. However, these events are unlikely since the probability of finding

results appearing to be different when in fact they are not, was less than one in a hundred ($P \leq 0.01$). Furthermore, potential errors were minimized by using two databases and alternative keywords. Another potential source of error could be associated with the fact that not all countries appeared to submit their graduate theses to *Dissertation Abstracts International.* Although the list of contributing countries appears to lack some major potential contributors (i.e., France), that list seems to be accurate at least regarding the US and Canada. Another potential source of error could develop if the sample of herds investigated were not representative of those of New York State. However, the mean milk production (6,449 kg/cow per year, Table 5) of the sampled herds was not statistically significantly different from that of New York State.[28] Moreover, herds sampled included progressive farms, which voluntarily request bacteriological testing (which is associated with low somatic cell counts, or SCC), as well as farms with high SCC. Thus, there was no obvious indication that the herd sample reported in this study is not representative of the herd population of New York State. Finally, adoption of bacteriological testing is not the only way to assess milk quality. Dairy herds are also assessed for milk SCC, a practice adopted in 1993 by 28% of the US herds which produced 51% of the milk.[28] Since there are no reports on whether herds not receiving bacteriological testing (etiologic diagnosis) receive information on SCC (indirect predictor of udder infection), the actual percentage of herds monitoring the status of mastitis should be somewhere between 39.7% (assuming complete overlapping of these two services) and 67% (assuming no overlapping).*

Because of these limitations, this study should not be regarded as a hypothesis-testing but as a hypothesis-generating study which should be followed by further testing.

Assessment of the veterinary extension-related research literature

References sorted by two databases, although differing in the number of articles retrieved with the same keywords (which reflected differences in the number of journals and years included by *CAB* vs. *Agricola*), yielded a similar pattern (Table 1). References sorted by *CAB* under *extension* indicated a larger agriculture publication output than that of veterinary medicine. The emphasis of extension research within all agricultural fields was 8.5 times greater than the veterinary counterpart (Table 2).

* Thus, even a conservative estimate suggests that at least one third of New York herds do not appear to request bacteriological culture of their raw milk.

In addition, social sciences (economics, education, evaluation, communication and sociology) explained higher percentages of the agricultural extension publications than in the veterinary literature (Table 1).

Agricultural extension did not seem to emphasize *bovine mastitis*, which seemed to be regarded as a veterinary topic. The amount of published research on bovine mastitis extension-related topics was negligible (e.g., only one study investigated adoption of bacteriological culture) (Table 2).

These findings suggest a relative weakness of the veterinary extension and mastitis-related knowledge base in the Americas. Although it might be argued that some extension publications may be published outside the peer-reviewed literature (and therefore, these findings might underestimate the actual publication output) these findings, rather, appear to support the opposite alternative. That is, that the lack of basic research (usually reported as peer-reviewed literature) limits the amount of all (peer- and non-peer reviewed) publications.

These findings appear to be related to a difference between agricultural and veterinary colleges in terms of disciplinary configuration.[3] Agricultural colleges have integrated social and other sciences with biological sciences and created departments with the purpose of improving utilization of professional recommendations (i.e., extension) at least since the classical studies on Iowa corn farmers implemented in the 1940's.[28] In contrast, veterinary colleges seem to lack academic departments or programs where technology transfer of veterinary expertise to animal agriculture is emphasized.

Assessment of graduate theses' disciplinary contents

While the actual contents of research publications were assumed to be validated by usage of various keywords and databases, contents of education programs were assigned by reading individually each thesis' abstract in its entirety at least five times by a panel of veterinarians with expertise in various fields. Therefore, we feel confident that the assignment of disciplinary contents reported here is a valid estimate of the implicit collective curriculum in the area of PBM.

Analysis of disciplinary contents of educational programs appeared to agree with analysis of research outcomes: no emphasis on major disciplines such as economics, education, communication were noted, nor on interdisciplinary approaches. Molecular biology appeared to have only a minor relevance.

Evaluation approaches such as this may help identify lacking disciplines (and interdisciplinary configurations) needed to improve the impact of graduate education

programs. Analysis of research and education disciplinary contents is an evaluation approach that may identify early and rapidly new emerging fields and technologies. We postulate that this approach may facilitate anticipatory development of educational programs. For instance, this approach could be used in the process leading to determine a thesis dissertation topic.

Adoption of veterinary recommendations for prevention of bovine mastitis

This is the first study that investigated the adoption rate of these five practices in New York State. In spite of the limitations indicated above, findings agreed with the only other study that investigated adoption of culturing raw milk for identification of mastitis-related microorganisms.[25] That study reported 10% of herds routinely submit bulk tank milk samples for culture; 13% of herds routinely submit quarter milk samples for culture, 25% of herds never request bacteriological testing, and 62% of herds occassionally submit milk samples for culture (n=73 dairies). Therefore, both studies appear to indicate a significant lack of adoption. Bacteriological testing is a valuable practice because it enables etiological diagnosis of mastitis, and therefore, specific courses of action aimed at its prevention. Economic losses associated with *Streptococcus agalactiae, Staphylococcus aureus* and *Mycoplasma bovis* in herds not bacteriologically tested could exceed 13 million dollars in New York State (Table 4). The proportion of closed herds (i.e., not introducing replacement animals) was less than 50% among surveyed herds (Table 5). This suggests that a significant percentage of the herds may introduce replacement animals which (according to the estimated rate of bacteriological testing) did not appear to be tested. Although we do not know the actual percentage of New York farms that actually have "closed herds", these findings indicate that economic losses due to *Strep. agalactiae* could be significantly reduced in New York State if bacteriological testing and closed herds were adopted massively and routinely.

One relevant factor to explain adoption of innovations in dairy farms is the cognitive-communication bases of dairy workers. Previous studies on adoption rates of practices related to PBM have surveyed dairy *managers*,[19,22,24] or *producers*.[20,23] However, none of these studies documented *milkers'* cognitive base regarding the biology of bovine mastitis. We postulate that situation-specific, interdisciplinary research (including social and other sciences) may be required in order to diagnose first, and design and implement interventions later, aimed at inducing *behavioral change*.[30]

Conclusions and recommendations

Conclusions

This study both provided data which suggest that research, education and professional practices need to be inter-related, and showed a tool to facilitate that interconnectedness. It is concluded that the veterinary paradigm involving bovine mastitis-related research, education and practice may benefit from broader interdisciplinary inputs. Current research and education programs appear to include rather narrow disciplinary contents. This apparent lack of broader disciplinary inputs in research and training appeared to be associated with lack of adoption of preventive practices.

Recommendations for program evaluation, policy and program development

These findings identify areas where new interdisciplinary research, education and services may be needed. With regard to the knowledge generation and dissemination subsystems (research and conventional education), academic institutional research might systematically produce information on research and education contents and trends of academic programs of which this study is an example. In addition, research involving economics (i.e., determination of costs vs. benefits of alternative, molecular biology-based diagnostic tests for detection of mastitis-causing pathogens) and epidemiology (i.e., determination of sensitivity and specificity of current diagnostic tests) are suggested.

In the dissemination subsystem, interdisciplinary, multi-person graduate education projects (in which teams of graduate students specialized in different fields could undertake complex issues and complement their work) could be associated with traditional (specialty-oriented) programs. Evaluation research techniques such as *concept mapping* could be applied to identify contexts relevant to other academic areas.[31]

With regard to knowledge use (extension), broader interdisciplinary research (including communication and education), oriented to promote farm workers' behavioral change is suggested. In addition, new distance education program and electronic mail communications may empower veterinary practitioners and farm workers.

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